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Applying risk and resilience metrics to energy investments

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MBA PROFESSIONAL REPORT

APPLYING RISK AND RESILIENCE METRICS TO ENERGY INVESTMENTS

December 2015

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APPLYING RISK AND RESILIENCE METRICS TO ENERGY INVESTMENTS

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

B/C	Benefits to Cost Ratio
CAPT	Captain
CEO	Chief Executive Officer
CFS	Center for Sustainability
CH4	Methane
CHP	Centralized Heat and Power
CNIC	Commander of Naval Installations Command
CO2	Carbon Dioxide
cu. Ft.	Cubic Foot
DOD	Department of Defense
DOE	Department of Energy
DON	Department of the Navy
EI&E	Energy, Installation and Environment
EISA	Energy independence and Security Act
EO	Executive Order
eROI	energy Return On Investment
FY	Fiscal Year
GEJE	Great East Japanese Earthquake
GW	Gigawatt
HME	Homemade Explosive
HVAC	Heating, ventilating and air conditioning
IED	Improvised Explosive Device
kW	Kilowatt
KWh	Kilowatt Hour
LED	Light-emitting Diode
MADA	Multiple Attribute Decision Analysis
MAUA	Multiple Attribute Utility Analysis
MAUT	Multiple Attribute Utility Theory
MDCOA	Most Deadly Course of Action
MLCOA	Most Likely Course of Action
MWh	Megawatt Hour

NAVFAC	Naval Facilities Engineering Command
NDAA	National Defense Authorization Act
NO2	Nitrous Oxide
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NSAM	Naval Support Activity Monterey
O&M	Operation and Maintenance
OASD	Office of the Assistant Secretary of Defense
OPEC	Organization of Petroleum Exporting Countries
PG&E	Pacific Gas & Electric
QER	*Quadrennial Energy Review*
RE	Renewable Energy
ROI	Return on Investment
RPG	Rocket Propelled Grenade
SECNAV	Secretary of the Navy
SM	Sendai Micro Grid
SST	ShotSpotter
TC	Total Cost
TOC	Total Ownership Cost
U.S.C.	United States Code
VEES	Value of Electrical Energy Security

EXECUTIVE SUMMARY

The Department of Defense views low total ownership cost as the number one priority during the energy investment process. In today's fiscally constrained environment, costs cannot be ignored; however, Secretary of the Navy Ray Mabus' goals of energy security and independence are unattainable without considering the full breadth of energy decision variables. The energy return on investment tool (eROI), serves as the status quo for energy investments. While eROI provides a framework for making energy decisions, the tool is flawed because it does not include the intangible and qualitative metrics of energy risk and resiliency. Cost metrics account for 39% of the decision for an energy project, while risk factors such as the price volatility of fossil fuels, grid overload probability, vulnerability of substations to domestic terrorist attacks, and the effect natural disasters have on fossil fuel production and distribution do not receive consideration. This neglect leaves naval installations vulnerable to avoidable risk and further weakens the resiliency of an energy infrastructure. Cost metrics cannot serve as the only deciding factors for energy projects because they do not contribute to energy security and independence.

The literature consistently notes that energy risk and resiliency significantly impact the effectiveness of energy projects—particularly energy generation. Incorporating risk and resiliency into energy decision making is challenging because capturing and quantifying intangible risk factors is difficult and subjective. However, relevant literature concludes that consideration of risk and resiliency will affect decision making by allowing leaders to make more informed and comprehensive decisions, potentially leading to different conclusions regarding energy project selection.

For this project, we used Multiple Attribute Utility Theory (MAUT) to develop an energy decision-making model that identifies and quantifies risk and resiliency factors. In contrast to the status quo model, eROI, the new model organizes energy considerations into four equally weighted categories: cost, risk, resiliency, and policy, all weighted at 25% each. The model provides a framework that accounts for quantitative data such as cost and savings over time, and qualitative data such as price volatility of fossil fuels and

the storage ability of an energy project. The model is flexible and easily adaptable by modifying the weights of each category based on perceived value as well as adding and subtracting attributes of each category. Ultimately, the new model is a more comprehensive tool than the status quo.

To validate the new model, we collected and analyzed data on an alternative energy generation project known as the Bloom Box. The Bloom Box provides reliable power independent of the commercial grid, which ultimately increases energy security through reduced risk and increased resiliency. We analyzed the Bloom Box under the current energy investment tool, eROI, and then again with the energy decision model developed for this project.

Under eROI, we found that the Bloom Box receives a very low overall score because the net present value (NPV) over the ten-year expected life span is -$600,135, with a payback period of over 37 years. Based on this metric alone, the Bloom Box would never receive consideration as a viable project because eROI places such a high emphasis on cost. However, when evaluated using different metrics under the new model, Bloom Box is found to provide naval installations with a significant increase in energy reliability, security, and independence. This gain toward a secure energy infrastructure would never be realized using eROI because the project would be dismissed immediately after evaluating the financial metrics.

Continued research is necessary to further develop and validate the model. We recommend that data be collected on energy generation projects to evaluate under the new model and eROI. We hypothesize that the outcome differences between the same project using two different models will further prove that risk and resiliency affect decision making when weighted similarly to cost metrics.

We conclude that today's energy investment process lacks the inclusion of risk and resiliency factors necessary to provide energy security and independence. While cost metrics such as NPV cannot be ignored as the DOD adjusts to constrained budgets, the overreliance on an unstable commercial grid leaves shore installations with too much risk. The question for energy planners and leaders is this: What is an acceptable level of

risk? Since current energy decisions are not inclusive of a full scope of risk, that question remains unanswered. If cost must remain the primary consideration moving forward, then the question becomes: How much cost savings must a project generate to accept a higher level of risk and lower level of resiliency?

The implied objective of the model is not necessarily to show that considering the full scope of risk and resiliency will always lead to a different decision, but rather to illustrate that under certain conditions the outcome will be different. A project scores differently when the perceived value of cost, risk, resiliency, and policy vary.

The Navy perceives eROI as a comprehensive tool for energy investments, but the model omits important factors of risk and resiliency, thus exposing shore installations to increased risk. Today, energy security is at the mercy of the national power grid. Partially to blame for this flaw is an overemphasis on cost metrics and an undervaluation of risk and resiliency. The new model developed for this project improves upon the status quo and places the Navy closer to Secretary Mabus' goals of energy security and independence.

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I. INTRODUCTION

A. DISCUSSION

The Department of the Navy's (DON) strategy for energy security directs shore installations to invest in renewable energy so that they become less reliant on the aging and vulnerable commercial grid (Department of the Navy, 2012). Therefore, installations must re-evaluate their energy infrastructure in order to meet strategic goals outlined by the president and Congress in a fiscally responsible manner. Naval installations have a strong dependence on energy supply and the smooth continuity of its delivery. Power plants and energy distribution stations are becoming larger and more complex as installation size and demand grow, requiring a real time balance for supply to meet demands. Computer systems governing the normal functionality and mission critical operations of installations rely directly on this continuous energy supply.

The current Department of Defense (DOD) energy acquisition and investment strategy prioritizes low total ownership costs (TOC), providing reliable energy to critical infrastructure, maintaining compliance with federal law and policy, and minimizing consumption. While these factors are certainly critical to providing secure energy and a reliable infrastructure, the list is not comprehensive. Two major considerations are overlooked: energy risk and energy resiliency. While risk and resiliency may receive discussion and consideration during an energy project evaluation, they are not prioritized appropriately, if at all.

Energy investment decision making fails to incorporate intangible risk factors such as the price volatility of fossil fuels, grid overload probability, vulnerability of substations to domestic terrorist attacks, and the effect natural disasters have on fossil fuel production and distribution. Additionally, resiliency factors, such as localized generation, energy conservation, and the ability to prioritize power distribution, are lacking from the current energy investment decision process. This neglect leaves installations vulnerable to mission failure through increased exposure to risks, thereby reducing their ability to provide secure and reliable energy. Incorporating risk and

resiliency factors into energy project evaluations is necessary in order to make comprehensive energy investment decisions.

B. OBJECTIVE

The purpose of this research is to develop a more comprehensive energy investment decision model that includes intangible factors related to risk and resiliency along with traditional considerations such as cost metrics and policy mandates. Furthermore, this project identifies how gaps and shortfalls in the current DON energy investment model lead to increased exposure to avoidable energy risk. The end state of this project is a functional model that energy planners can utilize to improve energy infrastructure at shore installations through risk mitigation and improved resiliency.

C. KEY TERMS

To understand the concepts and methodology of this research, energy security, energy risk, energy resilience and energy independence are defined in the context of the DOD.

Energy security for the DOD means having "assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs" (Assistant Secretary of Defense for Operational Energy Plans and Programs, n.d.). This definition does not mention risk or resiliency; however, throughout this paper, energy security is used as a term inclusive of energy risk and energy resiliency.

We found no standard definition for **energy risk;** however, literature generally refers to energy risk as a function of energy security. The lower the level of perceived energy security, the higher the risk, and vice-versa. The risk factors previously mentioned in the problem statement are not all-inclusive, but they are a critical component in understanding our interpretation of energy risk and the "all-in" cost of installation energy.

The definition of **energy resilience** varies slightly among organizations due to the complexity and scope of what the organization aims to accomplish. The Office of the Assistant Secretary of Defense, Energy, Installations and Environment (OASD[EI&E]) (n.d.) defines DOD energy resilience as "the ability to prepare for and recover from

energy disruptions that impact mission assurance on military installations." The definition provides this research with a broad foundation of what energy resilience within the DOD should encompass, leaving much room for interpretation. With the subjectivity of this definition, an unlimited number of dynamic factors may be included when determining what makes an installation's energy infrastructure resilient, creating complexity when pinpointing the value of components in terms of resiliency.

According to the DON (2010), "**energy independence** is achieved when naval forces can rely only on energy resources that are not subject to intentional or accidental supply disruptions. As a priority, energy independence increases operational effectiveness by making naval forces more energy self-sufficient and less dependent on vulnerable energy production and supply lines."

D. NATURAL DISASTERS

"DOD installations in the United States rely on the commercial electricity grid for 99 percent of their electricity needs" (Samaras & Willis, 2013, p. iii). In other words, installations assume all the risk associated with the inability to conduct missions during a commercial gird outage. Yet, DOD policy does not consider many important risk factors, such as probability of natural disasters, when making energy investments. During a disaster of any magnitude, shore installations often serve as a central hub in coordinating recovery efforts, rescue missions and providing medical relief, requiring them to be more resilient than any other customer reliant on the commercial grid. Natural disasters pose a significant threat to a shore installation's ability to carry out that mission as critical weaknesses of the grid are exposed.

The Great East Japanese Earthquake (GEJE) of 2011 is evidence of the devastation that natural disasters have on an energy infrastructure. Approximately 7.4 million homes were without power, and the Tohoko and Tokyo electric companies were still unable to produce 27 GW of power a full 10 days after the disaster (Inajima & Okada, 2011). Months later, during the peak of summer, the two companies announced that electricity supply would fall short of norms by 7 to 10 percent. Lacking a formal energy disaster plan, the Japanese government response was reactionary. Rolling

blackouts and reduction mandates for homes and businesses were implemented for the next several months as power was restored (Kimura & Ken-ichiro, 2013).

Additionally, the Yokosuna Naval Base and Misawa Air Base, home to two squadrons of F-16 fighter jets, lost electricity and telecommunications capabilities (Military Personnel, 2011). Four full days after the GEJE only minimal power was restored, leaving installations struggling to execute critical missions and humanitarian aid efforts to the population. More importantly, however, is the installation's exposure to risk of operational failure and an inability to respond to a deliberate attack.

The GEJE reveals vulnerabilities in the energy infrastructure and further stresses a need to incorporate risk factors and resiliency metrics into energy investments. The probability of natural disaster occurrence in a specific region along with the assessed range of damaging effects is not considered when evaluating an energy project. A decision model that incorporates these considerations mitigates unnecessary risk at shore installations and further evaluates an energy project beyond the scope of just costs.

E. INTELLIGENT ADVERSARY

The possibility of hostile attacks within the United States requires increased security to protect domestic energy grids and infrastructure that are vital to civilian infrastructure and DOD installations. Unlike natural disasters, an adversary can adapt its plan of attack to maximize effects on the identified vulnerabilities. Therefore, risks associated with natural disasters and deliberate attacks differ and should be evaluated independently of one another. Additionally, an intelligent adversary's potential targets and goals vary, making the risk for negative impacts on energy infrastructure and society difficult to predict and defend against.

According to the Incident Review Center SST (2014), California's Metcalf Substation, which supplies power to most of central California's Silicon Valley, lost power for four hours when attackers fired assault rifles, destroying 17 of 19 transformers. The same study indicated that the security response was slow, allowing time for the attackers to fire over 100 rounds of 7.62mm ammunition, causing more than $15 million in damages. The Incident Review Center further stated that power was rerouted,

eventually, and prolonged blackouts were avoided. However, due to the limited availability of parts, and the range of damage, repair crews needed approximately four weeks to return the substation to full capacity.

This single attack raised awareness to the vulnerabilities and lack of resiliency in energy infrastructure. From a macro perspective, the total damage from the attack was minimal: a 20-minute attack that caused $15 million in damage and took four weeks to repair (Incident Review Center SST, Inc., 2014). The most valuable lesson, however, is the potential for disaster and the damage that *could have been caused* if a similar attack were executed on a larger scale with more coordination and firepower. Fortunately, grid monitors restored power within four hours after rerouting electricity but had this been a simultaneous attack on multiple substations, the technology capital of the world could have been without power for months. The economic impact of Silicon Valley without power for a prolonged period would have disastrous effects.

A similar scenario is realistic for critical naval installations such as Naval Air Station Lemoore, home to all F/A-18 strike fighter squadrons on the west coast. If Lemoore were without power for a prolonged period, the squadrons would lack the ability to conduct missions. Training missions and peacetime operations are sacrificial, but what if Lemoore had no power during an actual domestic attack and the fighter squadrons were necessary for homeland defense? Without factoring in the potential for deliberate attacks to energy investments, the substations and infrastructure on DOD installations are exposed to unnecessary risk.

The Incident Review Center SST estimates that 2,000 electrical transformers throughout the U.S. provide power to three main hubs that feed and distribute power to the entire country. After the Metcalf incident, investigations concluded that most substations are extremely vulnerable to attack due to their remote locations and lack of resiliency (Incident Review Center SST, Inc., 2014). While most critical energy infrastructures have backup generation, they are designed to provide power for just a few days. Yet, substations and other energy generation systems require months to replace critical components such as transformers. DOD installations rely too heavily on short

term and unreliable back up power generation methods and are unprepared to conduct operations during an outage that lasts longer than just a few days.

Since current energy investment decisions over-prioritize costs and under-prioritize risk and resiliency, a new decision-making model is necessary that redistributes the amount of weight placed on each decision factor. A forward thinking and farsighted approach must occur during the procurement and investment stages of energy projects to mitigate the risks and potentially disastrous consequences associated with an intelligent adversary attack

F. DOD AND DON ENERGY GOALS AND OBJECTIVES

The DOD measures progress toward energy goals against the following:

- The Energy Independence and Security Act (EISA) of 2007
- Executive Order 13423 and 3514
- Energy Policy Act of 2005
- Title 10 U.S.C. 2911(e)

Table 1 defines each goal and shows each service's progress as of FY 2014.

Table 1. FY 2014 DOD Progress toward Facility Energy and Water Goals

Goals & Objectives	Metric	Entity	FY 2014 Performance	FY 2014 Target
Reduce Facility Energy Intensity relative to FY 2003 baseline (EISA 2007)	British thermal unit (Btu) of energy consumed per gross square foot of facility space.	DoD	-17.6%	-27%
		Army	-15.2%	
		Navy	-20.6%	
		Marine Corps	-18.7%	
		Air Force	-22.3%	
Consume more electric energy from renewable sources (EPAct 2005)	Total renewable electricity consumption as a percentage of total facility electricity consumption	DoD	3.5%	7.5%
		Army	2.0%	
		Navy	2.1%	
		Marine Corps	9.1%	
		Air Force	5.7%	
Produce or procure more energy from renewable sources (10 U.S.C. 2911(e))	Total renewable energy produced or procured as a percentage of total facility energy	DoD	12.3%	25% by 2025
		Army	11.3%	
		Navy	26.5%	
		Marine Corps	5.2%	
		Air Force	6.7%	
Reduce Potable Water Intensity relative to FY 2007 baseline (EO 13423)	Gallons of water used per square foot of facility space.	DoD	-21.5%	-14.0%
		Army	-27.1%	
		Navy	-10.5%	
		Marine Corps	-27.7%	
		Air Force	-21.9%	
Reduce Petroleum Consumption in non-tactical vehicles relative to FY 2005 baseline (EISA 2007, EO 13514)	Gallons of gasoline equivalent of petroleum fuel consumed.	DoD	-30.2%	-18%
		Army	-38.4%	
		Navy	-19.4%	
		Marine Corps	-38.0%	
		Air Force	-11.4%	

Source: Office of the Assistant Secretary of Defense (Energy, Installations, and Environment). (2015). *Department of Defense annual energy ,management report: Fiscal year 2014.*Washington, DC. Author.

All the goals and objectives identified in Table 1 are centered on reducing demand and consumption and moving toward renewable sources. Omitted is any language regarding risk and resiliency. While reducing demand and increasing renewable sources does lower energy risk through less reliance on the commercial grid, the DOD energy strategy and measurement criteria does not appropriately prioritize a risk averse and resilient energy infrastructure for installations.

In addition to the DOD standard, the DON has established a more aggressive and demanding set of goals. In 2009, Secretary of the Navy (SECNAV) Ray Mabus made security and independence the top energy priorities for the DON, which also aligns with the president's energy goals. The goals and associated benchmarks for the DON are as follows:

1. Increase alternative energy use DON-Wide. By 2020, 50% of total DON energy consumption will come from alternative sources.

2. Increase alternative energy ashore. By 2020, DON will produce at least 50% of shore based energy requirements from alternative sources; 50% of DON installations will be net-zero.

3. Reduce Non-tactical petroleum use. By 2015, DON will reduce petroleum use in the commercial vehicle fleet by 50%.

4. Sail the "Great Green Fleet." DON will demonstrate a Green Strike Group in local operations by 2012 and sail it by 2016.

5. Energy efficient acquisition. Evaluation of energy factors will be mandatory when awarding contracts for systems and buildings (Department of the Navy, 2012, p. 3).

Similarly to the DOD's goals and objectives, the DON does not mention risk or resiliency in their energy strategy. We found no information later than 2010 showing the DON's progression toward their internal standard. This suggests that progress is not tracked and reported as closely and carefully as the DOD's goals and objectives.

G. ENERGY RETURN ON INVESTMENT

When evaluating energy infrastructure investments, the Navy Installations Command (CNIC) developed an eROI (energy return on investment) template to make decisions between energy projects for naval shore installations. The eROI tool is an Excel spreadsheet containing various questions and scoring scales that reflect a potential energy project's characteristics. The intent of the eROI is to ensure that energy decision makers consider cost, risk, and capability metrics of the project, while incorporating the DOD and DON energy goals. The eROI tool is composed of five key strategic drivers that are individually scored and imply an imputed value of the project. All energy projects are evaluated using this system to ensure that the energy policy set forth by the DON is being met and that the Navy will see an adequate return on capital invested. The eROI tool currently serves as the status quo for how the Navy makes energy investments and decisions at shore installations. The eROI process is explained in detail in a later chapter.

II. LITERATURE REVIEW

A. EFFECTS OF NATURAL DISASTERS AND DOMESTIC TERROR ON ENERGY

We reviewed three reports regarding energy disasters: two covering natural disasters and one from a direct attack on an energy grid. The critical link between such disasters and DOD is the installation. During an emergency, DOD installations commonly serve as the central hub in coordinating recovery efforts, rescue missions and providing medical relief. Therefore, DOD installations require the most resilient and reliable means of energy security in order to ensure mission success.

1. Report on Hurricane Effects on Energy Supply

In April 2013, The Office of Electricity Delivery and Energy Reliability and U.S. Department of Energy (DOE), published a report, *Comparing the Impacts of Northeast Hurricanes on Energy Infrastructure*. The reported compared the effects Hurricane Irene and Sandy had on energy infrastructure and energy supply. Both storms caused power outages to millions with average repair times consisting of five days for Irene and ten days for Sandy. The main consequences of the storms were a damaged energy infrastructure leading to the inability to transmit power from substation to substation, and distribute the power to customers. Additionally, the report noted that petroleum supply to the New York and surrounding metro areas was disrupted for several weeks following the storms due to extensive storm damage and power outages to refineries and marine receipt terminals.

This report is useful to our research because it exposes weaknesses in energy infrastructure and further identifies a near-sighted approach with respect to repair priorities. For example, the focus of local governments and power companies was repairing the damaged infrastructure as fast as possible, taking a short-term approach. This approach fails to address the long-term vision necessary for a more resilient energy grid. Resiliency was not improved after the repairs to energy systems following Hurricane Irene, proven by similar and more extensive damage caused by Hurricane

Sandy. If utility companies and government agencies had employed a decision-making model that implemented risk factors, then their energy infrastructure would have likely been resilient enough to withstand future storms.

This report fails to identify the full scope of energy resiliency. The petroleum shortage directly impacts energy resiliency through second and third order effects such as the unavailability of gasoline for the area, commerce disruptions, and logistics complications, which the report did not include. Resilient energy infrastructure extends beyond the installation's energy gird and distribution capability to the people controlling the system and their ability to provide support, maintenance and technical expertise.

The lessons learned from the hurricanes provide evidence that a diversified energy portfolio with multiple sources of renewable energy counters the effects of a disrupted petroleum supply chain.

2. Report on Earthquake Effects on Energy Supply

The report, *How Two Microgrids Fared After the 2011 Earthquake,* states that the Great East Japanese Earthquake and Tsunami (GEJE) interrupted 14 gigawatts of combined nuclear and thermal power generation used to service eastern Japan. As a result, the Tohoku Electric Power Company was unable to supply power to its customers; however, two microgrids successfully produced and distributed power after the GEJE, when the Tohoku megagrid failed. The Sendai Microgrid (SM) supplied power and distributed it to critical nodes during the GEJE aftermath due to its resilient design. SM resiliency resulted from its localized energy source in the form of a hardened natural gas supply infrastructure, along with the skill and improvisation of technicians (p. 54).

Similarly, Roppongi Hills, another microgrid, had a localized natural gas infrastructure that fueled turbines without interruption providing centralized heat and power (CHP). The resiliency of SM and Roppongi proves that a localized energy source can act as a lifeline to generate power in the event of disaster.

The authors note that for a grid to be truly resilient, it should have multiple methods of energy generation that can support each other when one method fails. For

example, Tokyo Gas is creating a secure energy system consisting of fuel cell CHP, natural gas gensets, solar thermal water heating, and standard boilers and chillers that will supply power to a business district in Tokyo (p. 57). This diversified energy portfolio incorporates a higher ratio of energy generation to load components, which reduces risk and increases resiliency. This is helpful for our research because diversification is an important risk factor to consider when making energy infrastructure decisions. However, further research is needed to identify additional risk factors.

As a result of the GEJE, Japanese companies are now prioritizing energy resilience. In emergency situations, when power availability is limited, efficient consumption can reduce the stress on a grid leading to a more resilient infrastructure. The authors identified that "lowering energy consumption contributes to both emergency energy resilience and cost reduction in normal conditions" (p. 57). This point contributes to our research because efficient energy consumption leads to risk mitigation and increased resilience.

A lesson learned from GEJE was that an energy contingency plan should include ranking and prioritizing critical nodes. Supplying energy to non-critical nodes during the aftermath of GEJE was counterproductive to supporting the core effort. Even if power can be generated, distribution to non-critical nodes degrades the effectiveness of the system. When power is limited over long periods of time, managing energy conservation becomes critical; therefore, a resilient energy system should have a predetermined distribution plan.

A significant gap in this article that relates to our research is quantifying risk and resilience. The authors mention that resiliency increased, but how is it measured? How can leaders make claims about increased resiliency without having quantifiable metrics to measure and compare against? This begs the question, was resiliency actually increased in the examples provided?

3. Report on Direct Assaults on Energy Supply

The report, *Mitigating Active Shooting Incidents and Sniper Attacks on the Bulk Power Grid,* analyzes a deliberate assault on California's Metcalf Substation and

highlights the vulnerability of the commercial power grid to physical attacks. The PG&E Substation supports the electrical needs for most of central California including the technology capital of the U.S., Silicon Valley. The report estimates that $15 million in damage was caused when individuals destroyed 17 transformers with rifles. The report further cites the unpreparedness of security forces allowed the attackers to fire over 100 rounds of 7.62mm ammo in 19 minutes before police arrived on scene. Utility workers needed more than four weeks to bring the substation back to full capacity.

The authors concluded that all substations' security (not just Metcalf) are neither prepared nor equipped to detect or prevent future attacks given the current protocols. The attack did however alert energy security officials to the weaknesses of substations. As a result, changes to detection and prevention security technologies are progressing.

PG&E published a summary of the Metcalf incident stating they will spend $100 million over the next three years on Metcalf security upgrades (Pacific Gas and Electric Company, n.d). However, despite technology advancements that will presumably result, an energy system is no more secure or resilient from attack if the technology is reactionary and not preventative. True resiliency against deliberate attack results when an incident is detected before it actually occurs but the security effort seems to be focused on detection.

This report is useful for our research because it shows us that shortfalls exist in the progression toward energy resiliency against intelligent adversaries. We can use the identified security gaps as risk factors and inputs for an energy investment decision-making model.

B. RISK

The literature on risk regarding energy investments is consistent: DOD makes energy investments based on the lowest, up-front cost, neglecting life-cycle costs and comprehensive risk factors. Military installations are too dependent on a fragile commercial grid, which leaves them vulnerable to mission failure.

1. Monetizing Energy Security

The *Monetizing Energy Security* white paper asserts that "DOD should closely consider the actual, all-in (i.e., levelized) cost of energy, beyond merely the delivered price per gallon or kw (kilowatt)" (p. 3). This levelized cost of energy includes the cost and risks associated with DOD's current energy procurement process. The paper identifies such risks as

- price volatility of natural gas and crude oil;
- grid overload;
- natural disasters and their effect on oil and gas production and distribution;
- sabotage;
- interruptions in fuel supplies to generating plants;
- dependence on a fragile and vulnerable commercial power grid, placing critical military and Homeland defense missions at unacceptable risk of extended outages; and
- terrorist attacks, physical and cyber. (pp. 3–6)

Since DOD does not account for these factors when making energy decisions and investments, installations assume unnecessary exposure to the risks listed above, leaving them vulnerable to potential mission failure.

According to the paper, DOD separates energy into two categories, operational and installation. The authors state that "while external costs are included in the accounting for operational energy, the opposite is true with respect to the methodology applied to energy required to sustain fixed U.S. DOD installations" (p. 3). Only the commodity market price is considered for installation costs. The distinction between operational and installation energy is important because the result is an undervaluation of installation energy.

The authors further claim that there are "no widely recognized financial metrics to monetize the value of energy security and reliability," (p. 10) which is a major contribution to the undervaluation of installation energy. However, "The National

Renewable Energy Laboratory (NREL) developed a methodology to quantify energy reliability for DOD, which assesses the Value of Electrical Energy Security (VEES). This produces a metric that characterizes an annual estimate of the cost of utility outages" (p. 10). The VEES is useful for our own research as it appears to be widely accepted as a means to quantify risk since it was used in multiple studies that we reviewed.

This article recommends that DOD work to monetize energy security but that it lacks the appropriate data collection to do so. According to the authors, the levelized cost of energy should include the cost of risk. This paper does not identify installation risk factors nor a solution or model to incorporate them into an energy decisions or investments.

2. Marine Corps Renewable Energy Planning and Installation Security

In *Analysis of Marine Corps Renewable Energy Planning to Meet Installation Energy Security Requirements*, the authors discuss the DOD reliance on the commercial grid and gas infrastructure to power training and operations, which places "mission critical-operations at risk" (p. xviii). The authors then suggest that a possible way to measure risk is to quantify the costs of interruptions, i.e., loss in productivity, food spoilage, etc. By measuring these factors, commanders can identify their installation's exposure to an unreliable grid in a quantifiable manner and develop strategies to mitigate these risks.

The article finds that the price volatility of oil and natural gas is a risk of investing in fossil-fuel based energy generation. A solution to this vulnerability is investment in renewable energy (RE) sources, since they do not have the same market volatility. "Price-risk mitigation enhances energy security when energy planners incorporate greater renewable resources over those rich in fossil fuels" (p. 10).

The authors are consistent with a trend throughout the literature that the cost of energy is price plus risk, not cost alone. One particular way to quantify risk is the cost of interruption, which can be quantified using NREL's VEES model. While interruption is an important factor in risk measurement, it is not the only consideration. In other words, an ideal energy decision-making model should incorporate more risk factors, such as

natural disaster probability, price volatility, and interruptions in fuel supplies to be more inclusive.

C. RESILIENCE

The literature on energy resilience consistently emphasizes that it is an important component of a secure energy infrastructure. However, resilience is rarely considered throughout energy investment decisions because of the difficulty in quantifying and measuring resilience.

1. Measuring Resiliency

The report, *Measuring the Resilience of Energy Distribution Systems*, published by the RAND corporation "reviewed literature on metrics for energy system resilience to help develop a framework for evaluating and improving the resilience of energy systems" (p. iii). The report was sponsored by the U.S. Department of Energy in support of the initial draft of the *Quadrennial Energy Review* (QER).

The article reviewed definitions of resilience from the fields of public policy, engineering and academia. The main focus of this point in the article was not to be redundant in presenting information but rather eliminate terms that were not consistent in describing system characteristics (Willis & Loa, 2015). The review pointed out that consistencies exist when companies attempt to define energy resilience. The four repeating elements from the report are

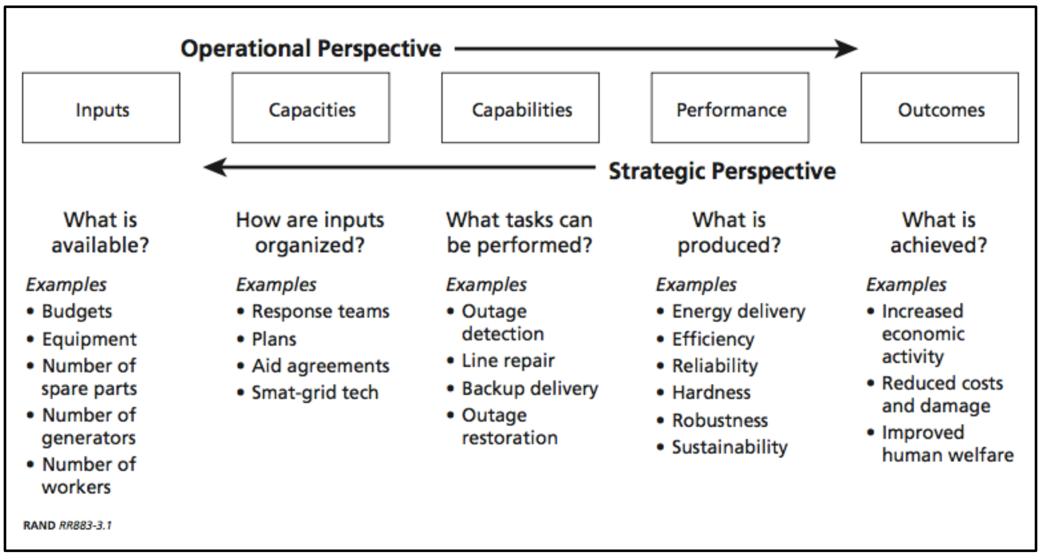
- resilience describes the state of service being provided by a system in response to a disruption
- the state of a system depends on how it was designed and how it is operated
- different responses will lead to different resilience at different costs
- resilience of a system also depends on the timescale (pp. 3–4)

These characteristics served as the foundation for a common resilience definition, however when defining metrics of resilience, other aspects such as service delivery, system design, system operation, disruption, costs and timescale are more important to

capture and serve as the foundation of metrics. While these aspects provide our research with a solid starting in organizing and developing specific risk and resilience factors, they are likely not all-inclusive for a DOD energy decision-making model.

When developing a framework to organize the specific metrics identified in research, the article outlined five categories to organize various metrics of resiliency. The RAND model provides decision makers with a consistent measurement framework that is applicable across varying energy systems. The framework is presented in Figure 1.

Figure 1. RAND Corp Framework for Organizing Resilience Metrics



Source: Willis, H. H., & Loa, K. (2015). *Measuring the resilience of energy distribution systems*. Santa Monica, CA: RAND. Retrieved from https://www.rand.org /content/dam/rand/pubs/research_reports/RR800/RR883/RAND_RR883.pdf

While this framework provides a useful way to organize metrics, it does not serve as a functional model. The categories and examples of inputs are helpful in establishing quantitative values but the lack of functionality and applicability to a specific case leaves a gap in our research. Further research is necessary to develop this framework into a model that decision makers can apply to energy investments at naval shore installations.

The article also provides a useful compilation of resilience metrics used among electric power, refined oil, and natural gas distribution systems, from the local to national

level. RAND provided the following metrics that are useful to our research: key replacement equipment stockpile, energy storage, number of workers, reserve/spare capacity, failure rate, resilience index, and survivability.

The article does not provide insight or information on systems that rely heavily on renewable energy. Many of the metrics may be well suited; however, further research is necessary in order to develop metrics specific to a renewable energy system.

2. Energy Resiliency at Barstow

A previous NPS thesis, *Energy Resiliency for Marine Corps Logistics Base Production Plant Barstow*, incorporated the use of renewable energy generation to the existing power consumption in order to reduce costs and increase energy infrastructure resiliency. The thesis provided cost estimates for implementing on-site power generation and micro-grid alternatives at Production Plant Barstow. The authors calculated the NPV of three different energy portfolios using capital cost, O&M, VEES, and a degradation factor over a 20-year time period. This directly relates to our research as a method of quantifying the resiliency built into an energy investment. The thesis concludes that an energy system with renewable sources is more resilient. However, the framework falls short of measuring the actual value of resiliency.

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III. METHODOLOGY

A. INTRODUCTION

As discussed earlier, energy planners do not consider the full range of decision variables when investing in energy projects. Cost and DOD policy are the driving force behind energy decisions while risk and resiliency are not prioritized appropriately. A critical assumption energy planners make is that the operating environment will remain in a normal state; however, risk mitigation and increased resiliency become extremely valuable when energy systems experience conditions outside the norm. Natural disasters, domestic terrorist attacks, and highly volatile and unreliable fossil fuel production and distribution networks create environments where assumptions about normal and steady-state operations do not hold true. Therefore, to achieve resiliency, energy planners should consider these environments and the associated risk factors throughout the evaluation process. The intent of this project is to create a simple method of quantifying intangible energy factors, which will better inform energy planners of the risks associated with a brittle energy infrastructure operating outside of a normal environment. This will allow energy planners to invest with a full scope of awareness.

B. MULTIPLE ATTRIBUTE BACKGROUND

Since planners for shore installations have many different options to consider with energy projects, the decision is complex, requiring an approach that appropriately weights the costs, life span, risks, and pros and cons of each project. Multiple Attribute Utility Analysis (MAUA) is a tool for "evaluating and comparing alternatives to assist in decision making about complex alternatives" (State University of New York University at Albany, 2012). MADA (multiple attribute decision analysis) and MAUT (multiple attribute utility theory) are other variations and are explained in detail later. For the purposes of this project, MAUA and MADA are synonymous, while MAUT refers to the overarching theory of multiple attribute analysis.

MAUA is intended to help planners make comprehensive decisions after determining the best choice through exploration of alternatives and consequence analysis. "MAUA models provide a way to score, evaluate, and compare possible alternatives and

offer a quantifiable method for choosing options" (State University of New York University at Albany, 2012). Comparing different energy projects across a standardized decision making model serves as a means to eliminate bias toward one particular project and objectively consider and evaluate each project compared with an alternative.

1. Why MAUA

The appeal of MAUA for an energy decision-making model is quantification, adaptability, and inclusion of all decision factors. First, quantifying intangible but important considerations such as the energy storage ability of a project, an infrastructure's reliance on the commercial grid, price volatility of fossil fuels, and the probability of natural disasters is a difficult and subjective task. Typical energy investments include primarily cost factors (initial costs, O&M, life cycle etc.), leaving other important considerations out of the decision process. MAUA provides planners with a method to identify and quantify intangible risk factors that can be used as inputs for a decision model.

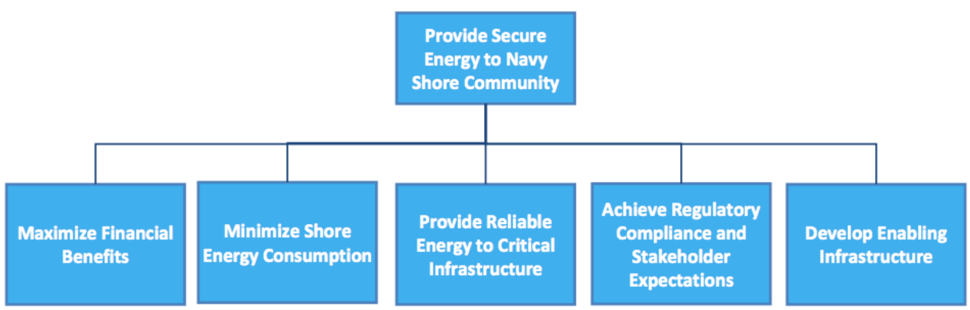
MAUA's adaptability makes it relevant to a continually evolving energy environment. As new technology emerges, the model can be adapted to include new decision factors that may not have been relevant in the past, and eliminate factors no longer requiring evaluation. MAUA's flexibility allows for comparison of an unlimited number of projects across an unlimited number of risks or decision considerations. Factors can be added and deleted as necessary allowing for real-time evolvement. Additionally, MAUA can be utilized as an evaluation tool for a shore installation's entire energy infrastructure, not just comparison of individual energy projects. We will discuss this application later.

Since most energy investments exclude risk and resiliency factors, MAUA is helpful in making all-inclusive decisions. The first two words, "Multi Attribute," explicitly state the foundation of this methodology. Each energy project has pros and cons that stretch beyond cost, yet they currently are not evaluated in a way that considers unique attributes, risk factors, and resiliency. By incorporating multiple categories and sub-categories of decision considerations, MAUA becomes an attractive solution to a one dimensional energy investment strategy.

2. eROI Analysis

The decision making model developed for this project incorporates aspects of the Navy's eROI model. Using MADA as the foundation, the eROI tool is intended to analyze potential energy investments and ensure they are risk based, capability focused, and will yield favorable ROI's. The output of the eROI tool is a single digit number, calculated as the estimated benefit to cost ratio (B/C) of the project being evaluated. More specifically, the B/C represents the present value of the project's anticipated contribution to energy cost savings and its contribution to supporting Navy energy objectives. A B/C ratio greater than 1.0 indicates the benefits outweigh the costs. Conversely, a B/C of less than 1.0 indicates the project will not break even. Figure 2 shows the drivers (blue boxes), the weight of each driver, the metric used to calculate the score of each driver and the measure used to quantify. The Navy's perception is that these drivers represent 100% of what is necessary to provide secure energy to shore installations.

Figure 2. eROI Drivers and Metrics



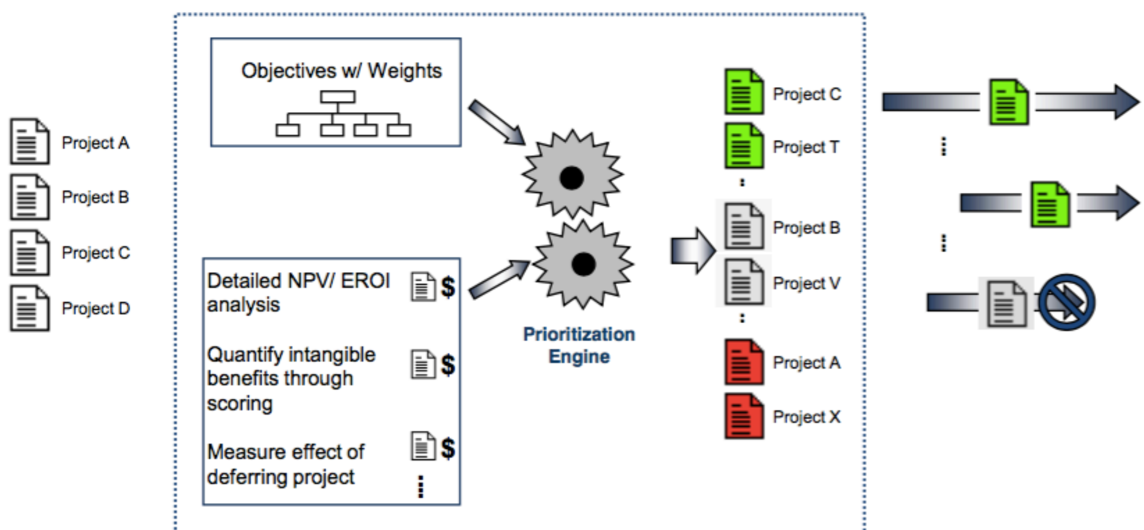
Metric	Financial Net Present Value (NPV)	Emissions	Scoring Scale • MDI • Outage Exposure • Incremental Backup	Scoring Scale • Mandates • Public Perception • Quality of Service	Scoring Scale • Data Improvement • Energy Flexibility • Tech Adoption
Measure	Dollars	CO2e	Scaling Questions	Scaling Questions	Scaling Questions
Weight	39%	9%	26%	13%	13%

Source: Commander, Navy Installations Command. (2011, December). *eROI template users manual.* Retrieved November 13, 2015, from http://www.districtenergy.org/assets/pdfs/2012-Campus-Arlington/Presentations/Bus-Dev-CEAC-Workshop/BIZDEV6BOYETTEIDEA-presentation-eROI-Templatev3.pdf

eROI evaluates both quantitative and qualitative data. The first two drivers shown in Figure 2, “Maximize Financial Benefits” and “Minimize Shore Energy Consumption” can be objectively and accurately measured because their performance metrics provide quantifiable data. The other three drivers however, contain subjective data and intangible metrics. To quantify these drivers and metrics, the eROI model uses a simple rating scale. For example, the “Develop Enabling Infrastructure” driver is composed of several subjective metrics. Using a scale of zero to ten or zero to one hundred allows the user to assess, evaluate and determine an appropriate score based on the perceived quality of each metric.

The application of eROI and how the Navy chooses energy projects is fairly straight forward. As shown in Figure 3, projects A, B, C, D, etc. are evaluated using the eROI tool and then assigned a B/C ratio or eROI score. Then, they are ranked and prioritized according to the B/C ratio from highest to lowest. The higher the eROI score, the higher priority. Pending available funding, the Navy begins work on an energy project at the top of the list and slowly works to the bottom of the list completing all projects with an eROI score greater than 1.0.

Figure 3. eROI Project Selection Process



Source: Commander, Navy Installations Command. (2011, December). *eROI template users manual.* Retrieved November 13, 2015, from http://www.districtenergy.org /assets/pdfs/2012-Campus-Arlington/Presentations/Bus-Dev-CEAC-Workshop/BIZDEV6BOYETTEIDEA-presentation-eROI-Templatev3.pdf

In short, the eROI tool collects the perceived important information about each energy project under consideration and evaluates it comparatively based on an output score.

3. eROI Gaps and Limitations

The eROI tool provides a robust framework for assessing energy investments; however, it falls short of capturing the entire breadth of factors effecting energy projects and infrastructure. The primary focus of eROI is the NPV of the investment costs. While NPV is an important factor, particularly as energy planners are faced with constrained budgets and sequestration, failing to consider risk and resiliency leaves energy projects and installations vulnerable to the potentially catastrophic consequences of natural disasters, domestic terrorist, and the fragile and unreliable commercial grid. Ultimately, risks that could be mitigated if the decision-making process was more inclusive, erodes the Navy's path to energy security and independence. In a fiscally constrained environment, costs cannot be ignored, however they should be viewed on a similar plain as other metrics that are strategic to the operation and life cycle of the system.

Naval leadership identifies cost as the dominate factor for energy projects, evidenced by the 39% weighting of NPV in the eROI tool. Captain James Goudreau, deputy assistant secretary of the Navy Energy, challenges the current eROI metrics, assessing that the tool fails to provide energy planners with the framework necessary to make the best decisions.

Goudreau identifies assumptions regarding the stability of the environment as a major flaw in today's energy decision-making process. Today's energy infrastructure provides reliable and secure energy under reliable and secure conditions. However, when installations experience conditions outside of the normal working environment, energy generation is neither reliable nor secure. A natural disaster, deliberate attack, or failure of the commercial grid has the potential to leave an installation without power for prolonged periods. The primary back up power source for most installations is diesel generators that are intended to provide electricity for one to three days. An installation that is required to conduct operations during an outage longer than a few days will likely fail if completely

reliant on power from diesel generators. Reliable and secure energy is most essential during severe conditions, yet these environments are not fully considered when evaluating energy projects. The eROI tool and energy planners fail to recognize that the resiliency of an energy project is not defined during normal operation but rather during stressful or extreme conditions.

eROI also fails to factor in the effect an outage has on readiness. During an outage, an installation's operational capacity is limited unless they have a more reliable means of back up than diesel generators. For example, a week's delay of fuel or logistical replenishment to deployed forces from a hurricane affects the readiness and capability of overseas operations. Unresilient back up generation is the result of a near-sighted approach. Power is provided for the first 24–72 hours but what happens after that? eROI does not capture the full scope of energy investment considerations.

The Naval Facilities Engineering Command (NAVFAC) assesses that eROI falls short of capturing the full scope of pros and cons of an energy project. For example, installation of a photovoltaic (PV) field supports many DOD and DON energy policies and decreases variable costs at the installation. A model that strongly favors cost metrics views a PV field as an ideal investment. However, eROI fails to realize the downside of such a project from a risk and resiliency lens. A limitation of renewable energy generation is storage capability and when the commercial grid fails, the amount of energy a PV can generate is irrelevant because it is not independent from the grid. While a PV field is a favorable investment from a cost and environmental perspective, it actually does very little toward energy security and independence. The eROI tool may return a favorable on a project but most shore installations are still at the mercy of the commercial grid and eROI does not properly reflect that risk.

A further limitation with the eROI tool is its adaptability. While the tool does provide planners with a logical framework to assess energy projects and compare them with alternatives, it is limited to comparing individual projects and does not serve as a means to evaluate an installation's entire energy infrastructure. If a Commanding Officer is concerned of his installation's energy generation and back up infrastructure, he currently has no analytical tool to provide an evaluation. A model is necessary that

provides leaders with energy information and metrics and information not just for a particular energy component or project but for the installation's entire energy infrastructure as well.

Placing too much value on the financial metrics of an energy project presents leaders with a biased and incomplete evaluation. Assessing and debating energy projects with a more complete list of metrics that include risk and resiliency, allows leaders to make better informed decisions regarding energy investments.

4. Pepperdine MAUA Application

The decision model developed for this project is largely based off of a case study conducted at Pepperdine University. The project combined MADA and MAUT to help Pepperdine's Center for Sustainability (CFS) prioritize multiple competing energy projects in an attempt to reach the university's goal of reducing electricity consumption on campus by 10%. MADA provides a systematic approach to complex decisions where a traditional structured approach is not sufficient. For example, a shore installation energy planner has the funding and flexibility to implement one of two options: 1) install solar panels or 2) initiate an energy savings plan. The traditional approach is to conduct some sort of cost analysis where initial costs, O&M, and long-term savings are calculated. However, as previously stated, cost is only one piece of the puzzle and other factors in addition to costs should be considered. Thus, the decision becomes more complex requiring further critical analysis. Since risk and resiliency factors are not typically quantified in the same manner as cost and savings, converting all comparative metrics to a common measurement unit is necessary to ensure an "apples-to-apples" comparison. MADA is a commonly accepted method to approach problems like this. According to the Pepperdine case, MADA consists of four steps in its most basic form:

1. Framing of the decision and identification of the goals and objectives to be achieved by the decision maker
2. Identify all decision alternatives and any related attributes that address the decision making objectives
3. Specify preferences, both for each of the individual attributes and between the attributes in the framework

4. Ranking of the decision alternatives according to the specified preferences, given the attribute data for each of the alternatives (Hahn, Seaman, & Bikel, 2012)

In the shore installation energy example, tradeoffs are necessary, requiring a debate of competing priorities. If the three major categories of consideration are risk, resiliency, and cost, each project will likely have a different score for each category. The solar panel project may come with high cost savings but little to no resiliency while the energy savings plan may yield lower savings but carry lower risk and high resiliency. The tradeoff in this scenario and the question for energy planners is how much cost savings must a project generate to accept a higher level of risk and lower level of resiliency?

Combining MAUT and MADA develops common units of measurement and specifies the energy planner's preference for each category. The Pepperdine case asserts that MAUT is applied via the following three steps:

1. defining attributes by which the decision objectives will be measured;
2. normalizing the measurement or scale of all attributes across all alternatives; and
3. weighting the preferences between those attributes (Hahn, Seaman, & Bikel, 2012)

The first step, defining attributes, is subjective and in the case of energy projects will likely change as technology matures. For example, a "resiliency" category might include attributes such as energy conservation and energy storage ability since they can have significant impact on the resiliency of an energy project. The attributes may change as conservation and storage technology develop.

The second step is accomplished by using a standardized scale such as a 0–10 score for each attribute. The last step is subjective. Preferences for attributes will vary depending on the perceived value of each

Using MADA and MAUT, Pepperdine developed the following seven-step process to assess competing energy projects objectively:

1. Identify alternatives;
2. Clarify the goals and objectives, and organize them into a hierarchy;

3. Identify measures;

4. Quantify measures for each alternative;

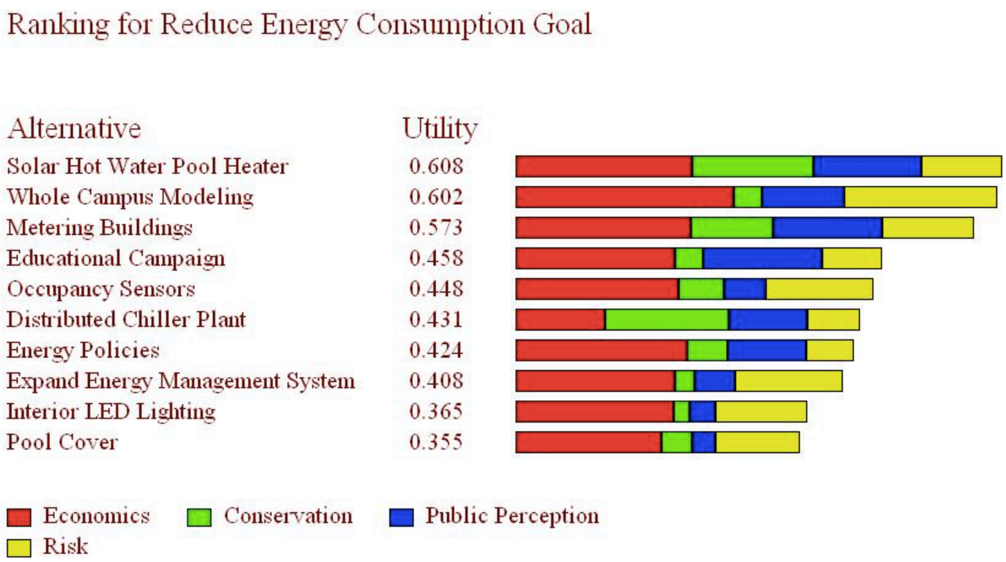
5. Delineate preferences for attributes;

6. Delineate preferences between attributes; and

7. Rank alternatives. (Hahn, Seaman, & Bikel, 2012)

The output of the Pepperdine model, shown in Figure 4, is a ranking of each alternative along with a utility for each category.

Figure 4. Pepperdine Case Study Results



Source: Hahn, W. J., Seaman, S. L., & Bikel, R. (2012). Making decisions with ultiple attributes: A case in sustainability planning. *Graziadio Business Review*.

CFS administrators hypothesized that “metering buildings” would be the best option to reach their energy reduction goal and were surprised to see that the model rejected their hypothesis. This type of realization is where MADA is valuable. Projects that would not have otherwise been considered are suddenly a primary option. Often times, without a measurable and objective method for considering alternatives, bias toward one particular project will cause that project to prevail. MADA minimizes bias and ranks projects objectively based on perceived value of goals and objectives.

C. HOW MAUA IS USED IN THIS PROJECT

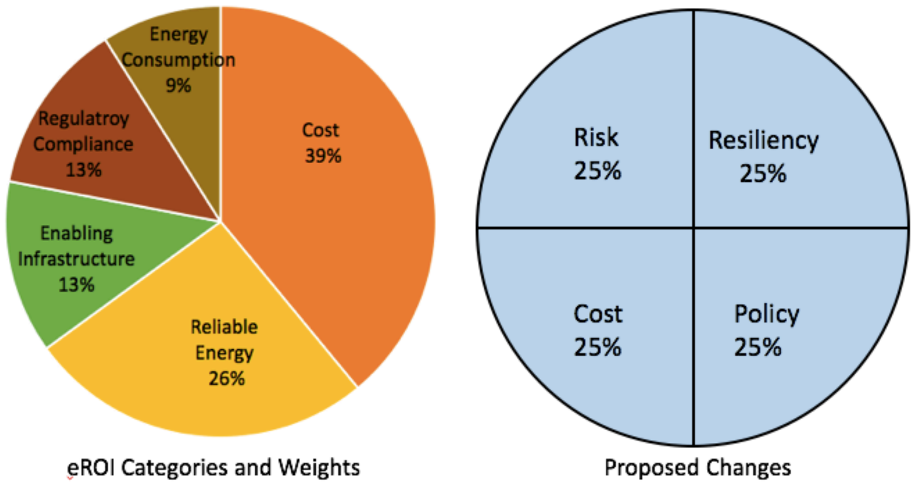
In order to incorporate environments outside the norm and influence energy planners to consider factors beyond cost, we developed a model that includes multiple attributes related to energy investments. This model allows the user to address what project alternatives to consider, gain a more accurate understanding of goals and expectations, and further allows for subjective input and important debate of the pros and cons of the projects. Using MAUA as the foundation, a seven-step model guides the end user (in this case the energy project decision makers) from project inception to completion. Our model utilizes the following steps:

- 1. Identify alternatives
- 2. Clarify the goals and objectives, and organize them in a hierarchy
- 3a. Identify fundamental categories
- 3b. Quantify fundamental categories
- 4a. Identify category attributes
- 4b. Quantify category attributes
- 5. Normalize category and attribute values
- 6. Calculate total project score and rank alternatives. (Hahn, Seaman, & Bikel, 2012)

D. MODEL EXPLANATION

Figure 5 represents the Navy's current weighting of energy categories according to eROI alongside the changes suggested for this project.

Figure 5. Comparison of current categories and weights vs. suggested changes



Adapted from Commander Naval Installations. (2011, December). *eROI template users manual*. Retrieved November 13, 2015, from http://www.districtenergy.org /assets/pdfs/2012-Campus-Arlington/Presentations/Bus-Dev-CEAC-Workshop/BIZDEV6BOYETTEIDEA-presentation-eROI-Templatev3.pdf

While the current method seems like a more inclusive model, the proposed model offers the same considerations in a more streamlined version with a redistribution of priorities. For example, the eROI category "Energy Consumption," which is valued at 9% is now part of the resiliency category in the new model, and "Reliable Energy" is part of both the risk and resilience categories. Nothing is sacrificed under the new model; the priorities are similar but with more emphasis on risk and resiliency and less on cost.

Figure 6 presents the energy decision-making model developed for this project. It consists of four overarching categories (risk, resiliency, cost, and policy) that total 100% of considerations when making energy investment decisions. Below each category is a list of attributes that define and describe each category. Using a Likert scale, each attribute is assessed according to the model description (detailed later in the chapter) and assigned a score between zero and five.

Figure 6. Energy Investment Decision Model

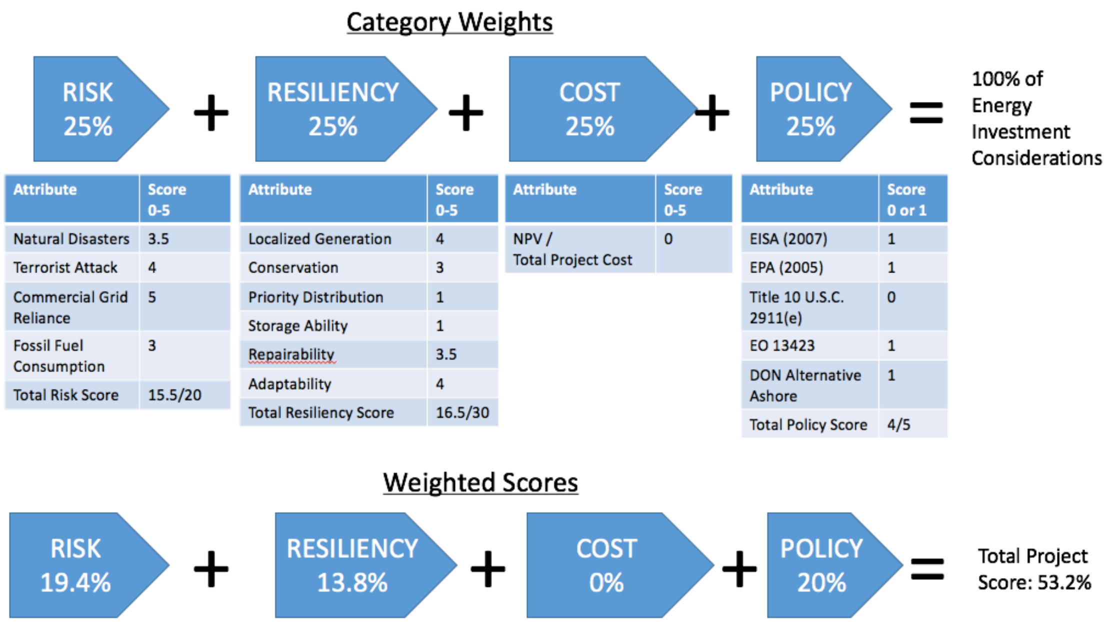


Table 2 is a description of the scoring scale for the model. Though the same zero-to-five scale is used for the whole model, each category is scored differently depending on the metric.

Table 2. Scoring Criteria and Metrics

Score	**Risk**	**Resiliency**	**Cost**	**Policy**
Metric	Does the project mitigate risk?	Is resiliency increased?	NPV/Total Cost	How many DOD/DON policies are supported by the project?
0	Risk is adversely effected	Resiliency is adversely effected	-51% and below	Supports 0
1	Risk is not effected	Resiliency is not effected	(-1)-(-50%)	Supports 1
2	slight improvement	slight improvement	0-49%	Supports 2
3	moderate improvement	moderate improvement	50-99%	Supports 3
4	significant improvement	significant improvement	100-149%	Supports 4
5	extreme improvement	extreme improvement	150% and above	Supports 5

Each category's attributes are summed and then weighted against their respective category's percentage. For example, if risk is valued at 25% and the category attributes sum to 15.5 out of a maximum score of 20, then the overall risk score is calculated as 25% x (15.5/20) = 19.4%, with the maximum score being 25%. The same step is repeated for each of the four categories and their respective attributes. The weighted scores from each category are then summed to yield a total project score. This process is repeated for each project or alternative. Therefore, if three energy investments are being considered, each project should be run through the model for a total of three project scores.

The first step in the process is to determine the alternatives. The model effectively compares the scores of each category and respective attributes across different options. For example, if a shore installation is considering installing a solar energy system, that technology should be compared to alternatives in order to identify strengths and weaknesses. Alternatives include wind power, geothermal energy, hydroelectric power, and any other reasonable substitution for solar. Since the output is a numerical value, having other projects to compare and contrast with provides more useful information than running just a single project through.

Since the concept of the model is new, foundational scores for the overarching categories (risk, resiliency, cost, and policy) do not exist. In other words, if a project scores a 19.4% in the risk category, is that acceptable, good, or bad? A standard for comparison will develop as the model gains fidelity after continued and prolonged use. The acceptability of a score will also vary with the perceived value of the category. The model uses an equal 25% weight for each category, but that may be easily modified if policy, for example, is perceived to have a lower value than any of the other categories.

The second step is to clarify the goals and objectives since they vary across organizations and at different levels of command. For example, an installation commander may have a short-term goal of reducing energy consumption by 10% over the next year. While, at the top of the goal hierarchy might be DON goal of increasing alternative energy use to 50% by 2020 or the DOD goal of increasing total renewable energy produced or procured as a percentage of total facility energy to 25% by 2025 (10 U.S.C. 2911(e)). The point of this step is to clearly state the goals and objectives and

prioritize them to ensure that the energy projects under consideration will enable goal attainment.

The third step consists of two parts: a) identify the fundamental categories and b) quantify them. For this model, the categories are risk, resiliency, cost, and policy. Theoretically, the number of categories is unlimited; however, the simplicity of this model is valuable to an organization as the category percentages and their respective attributes can be adjusted as necessary. Additionally, when comparing projects, the number of categories must be consistent so that the model produces comparable results. Evaluating one project under a model that utilizes four categories is not comparable to evaluating a different project under a model that utilizes five categories. Even though the total project score is always 100%, evaluating projects with inconsistent categories does not allow for an apples-to-apples comparison.

Part b, quantification of the categories, depends largely on the perceived value of each category. The method of quantification is simple priority based allocation represented by percentages. The number of categories may vary but when all the category's percentages are summed together, the total should always equal 100%. As Figure 6 implies, 100% of energy investment considerations fall into four categories weighted equally at 25% each. However, the user can easily adapt the model and modify the categories and their respective weights. Weighting the categories allows the user to identify priorities and determine a perceived value. In certain instances, risk may be a more valuable consideration than cost or policy. The percentages of each category should reflect priorities.

The fourth step also consists of two parts: a) identify category attributes and b) quantify them. Table 3 displays the categories and attributes selected for this model, which will each be described in detail later in the chapter. The attributes serve as a means of defining the category and further represent variances and considerations that will occur throughout the life cycle of the project. Similar to the categories from step three, a consistent number of attributes is critical to the functionality of the model. For example, if one project is run through the model with four risk attributes then the total possible risk score is 20 (four attributes x a maximum possible score of five = 20). If the model is then

manipulated to include a fifth risk attribute, then the total possible score is 25. The result of the two different projects would not be an apples-to-apples comparison. The adaptability and flexibility of the model is advantageous to energy planners so long as the number of categories and associated attributes remains consistent when comparing potential projects. Furthermore, the model is essentially a living document and should be updated, manipulated, and experimented with by energy planners as technology progresses and priorities shift.

Table 3. Categories and Attributes

Category:	**RISK**	**RESILIENCY**	**COST**	**POLICY**
Attributes:	Natural Disasters	Localized Generation	NPV/TC	DOD
	Terrorist Attack	Conservation		DON
	Commercial Grid Reliance	Priority Distribution		
	Fossil fuel consumption	Storage Ability		
		Repairability		
		Adaptability		

Part b, quantification of the attributes, is based on a Likert scale of zero (worst) to five (best). Energy planners will discuss and assess each category attribute and assign a value. For the attribute “natural disasters” in the risk category, planners debate such questions as:

- Where is the location of the installation/project, and what is the most probable natural disaster (hurricane, tsunami, tornado, earthquake, etc.)?
- What is the probability of occurrence?
- What effect would a disaster have on the logistical chain?

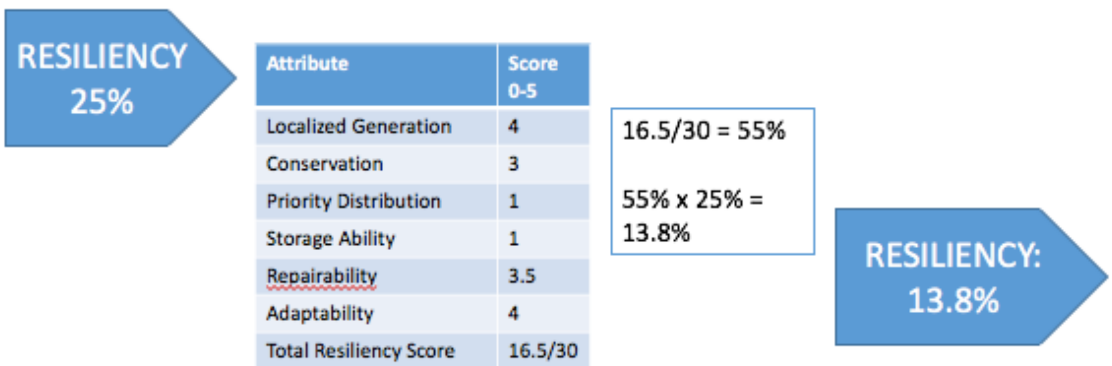
Another example: for the attribute “priority distribution” in the resiliency category, planners ask such questions as:

- Does the project allow for control of energy distribution?
- Will energy distribution from this project allow the mission critical nodes to receive energy before noncritical nodes?

A description of questions and considerations for each attribute is detailed later in the chapter.

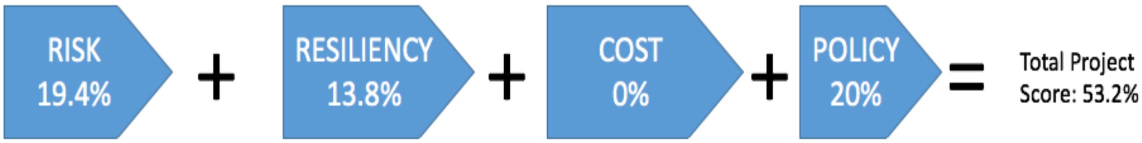
The fifth step is normalization. Since the categories are expressed in percentages and the attributes are scored from zero to five, they have to be normalized to a common scale. To normalize this data, the sum product is used. As Figure 7 shows, the resiliency category weighted at 25% is multiplied by the sum of the attributes (16.5 in this example) over the maximum score possible (30) for a total resiliency score of 13.8%. The same process is repeated for each category and its respective attributes.

Figure 7. Example of Fifth Step Evaluating Resiliency



The sixth and final step of the process is simply adding up the normalized data for single output score and then ranking the projects. Figure 8 depicts this process. The example project received a 48.2% out of a maximum score of 100% with four categories weighted equally at 25%. The project with the highest score is the best choice using this model.

Figure 8. Weighted Scores



E. CATEGORY AND ATTRIBUTE DESCRIPTION

The following is a description of each category's attributes. When scoring and evaluating an energy project, the following questions serve as a guide to ensure energy planners discuss the necessary points of consideration for each category.

1. Risk

a. Natural Disasters

1. Where is the location of the installation/project and what is the most probable natural disaster and how vulnerable is it to a hurricane, tsunami, tornado, earthquake, etc.?

2. What is the probability of occurrence? Look at past natural disasters and consider the frequency. For example, an energy project on the eastern shores of Florida has a high probability of experiencing a hurricane. Energy planners would relate this factor to the most likely course of action (MLCOA).

3. What is the range of effects? From the disasters discussed above, what is the worst damage possible? Referred to as the most deadly course of action (MDCOA). Energy planners should question the probability of the project enduring the range of effects. For example, could the project provide power during a Category 2 hurricane (MLCOA) or a Category 5 hurricane (MDCOA)?

4. What effect would a disaster have on the logistical chain? If the project is reliant on fossil fuels, can they still be distributed? Planners should also consider what effect non-local disasters would have. For example, would a natural disaster on the east coast disrupt fossil fuel production and distribution on the west coast?

5. A high score indicates that the energy project can withstand even the worst damage caused by a natural disaster. Therefore, the overall risk from a natural disaster is low.

b. Terrorist Attack/Intelligent Adversary

1. Does the installation/project supply power to mission critical nodes or installations? An energy project that supplies mission critical power is likely a more attractive target for a terrorist attack. If the project supplies power to non-mission critical nodes, then it is likely at a lower risk for attack.

2. Where is the location of the installation/project? Most energy infrastructures and substations are located in remote areas, which is ideal for an attacker. If the project will be located in a well-lit and highly monitored area, then the probability of attack may be lower when compared with a remote and isolated project.

3. What are the security measures in place to deter or prevent potential enemy action? Many substations are vulnerable due to their remote location and lack of security presence. A project located on a secure base with regular roving patrols carries a lower risk for attack than a project in a low population and remote area.

4. What is the range of effects from an enemy attack? As with natural disasters, consider the MLCOA and MDCOA. Could a terrorist attack destroy this project completely or just cause minimal damage? What type of weapon or method of initiation may be used? Small arms, automatic weapons, varying types of improvised explosive devices (IED's), rocket-propelled grenades (RPG's), and homemade explosives (HME) are among the possibilities.

5. What is the chance of a cyber attack on this installation/project? It is important to remember that terrorist attacks are not limited to physical. With the growing threat of cyber attacks, energy projects include protective measures to counter or mitigate the risk of such an attack.

c. Commercial Grid Reliance

1. Is the project/installation solely reliant on the commercial grid? Alternatively, does the project have an independent back-up source or smart grid that will continue to provide power during an outage.

2. What is the probability of brown or black out? While calculating a precise probability is unnecessary, past brown and black outs should be considered along with their severity, frequency, and duration.

3. What is the probability of grid overload? Again, a precise number is not needed but the fragile and decaying state of most commercial grids leads to a chance of overload.

d. Fossil Fuel Consumption

1. Is the project reliant on fossil fuel for energy generation? The more reliant a project on fossil fuel, the more risk it assumes. A primary risk with reliance on fossil fuels is price volatility.

   In the 1970s, the U.S. learned a painful lesson on the importance of energy security with the imposition of the OPEC oil embargo in 1973. The sudden loss of over a million barrels per day of oil imports from the Middle East caused gasoline prices to jump from approximately 35 cents a gallon to over a dollar per gallon. As a rule of thumb, a $10 increase in price per barrel of oil means a $1.3 billion increase to U.S. DOD's annual energy bill. Exacerbating fossil fuel price volatility is the average $84 billion per year that U.S. DOD spends securing overseas oil transit routes and infrastructure to defend America's fossil fuels reliance (Brower, et al., 2014).

2. Resiliency

a. Localized Generation

1. Does the project have the ability to generate power locally or is it 100% reliant on the commercial grid? This is an energy independence question. If the project can function independently of the commercial grid, resilience has increased.

2. Under what conditions can the project generate and distribute energy? What will inhibit generation and distribution? If the project can operate independently from the commercial grid, it will likely do so under normal operating conditions. However, the question here is asking if the project can maintain generation and distribution during an outage, natural disaster or another type of non-normal operating environment.

3. How much power does the project generate in relation to demand requirements? In other words, is there more demand than generation? Demand and generation data should be collected and evaluated to ensure adherence to demand reduction goals and that the project meets the minimum requirements.

4. Are generation methods diversified, or does power come from a single source? True resiliency is achieved when energy generation, transmission, and distribution is efficiently resourced. As discussed earlier in the literature review, the lessons learned from the GEJE provide evidence that a diversified energy portfolio with multiple sources of renewable energy counters the negative disruption effects from a natural disaster. One generation method (the commercial grid, for example) is a high risk, "all-

in" scenario. If the grid goes down, energy generation and distribution is dependent on the back-up method, if one exists.

b. Conservation

1. What effects does this project have on demand? Will the project promote demand reduction or will it increase usage? Conservation is an integral part of energy security and independence, which is reinforced through stated DOD/DON goals and objectives.

2. Is the project efficient? Efficiency is a subjective term so comparison against past or current projects and usage rates is a worthwhile measurement tool. A higher conservation score should be awarded to those projects using the most efficient energy resources and components (efficient lighting, appliances, and heating and cooling choices for example).

c. Priority Distribution

1. Does the project allow for control of which nodes receive energy? Will the mission critical nodes receive power before non-critical nodes? During an outage, mission critical nodes should receive power first. If the outage is prolonged, energy managers should have the ability to shut off power to non-critical nodes to ensure efficiency and conservation.

2. Can the installation conduct mission critical operations during an outage or disruption? If the answer is no, or partially no, then does the energy project support mission critical operations? Mission critical operations should be prioritized first so the priority distribution score should be lower if the project supports non-mission critical assets or functions.

d. Storage Ability

1. Can the project store excess power for later usage? A limiting factor in renewable generation is storage ability. For example, a solar panel system may be able to generate power all day long but the energy infrastructure is no better off if that power cannot be stored over long periods and utilized during critical times such as during an outage or natural disaster.

2. Other contributing factors to the storage ability score are: How much can be stored? (may be expressed in terms of a percentage of demand or in megawatts) and for how long? Can the stored energy be used during emergency or outage? A project that has limited or no storage ability should receive a very low score.

e. Repairability

1. Are repair teams on site? What is their response time? What is the knowledge level? Can they repair every part of the system? Energy resiliency extends beyond the system or project itself to the quantity and quality of the repair and maintenance team. A team with experience and familiarity with the energy project or infrastructure is a valuable resource during an outage or emergency. The repairability score should closely consider the technical knowledge and experience level of the operators in charge.

2. What back up parts are kept on hand? How long will it take to order parts not kept on? How long to manufacture if not available right away? Since energy projects are unique, repair parts are often manufactured by a single provider, which may lead to extended waiting periods. Often times, specific components are made to order, extending waiting periods for months or longer. An energy project could potentially be nonoperational for months while waiting for a manufacturer to ship parts or have them made.

f. Adaptability

1. How does the project fit in with existing infrastructure? Does the infrastructure require major changes in order to accommodate the new project? A resilient energy project should be adaptable to new and older technology as to minimize potential future costs.

3. Cost

To capture the financial parameters of a project accurately, energy planners estimate cash outflows and inflows over the lifetime of the project. Estimating the initial investment (capital), Operation and maintenance costs, cost savings or income generation, and other associated costs allows for a net present value (NPV) calculation, which provides a snapshot of the financial condition of a potential investment. Since energy projects have a wide range of NPV's that depend on size and scope, scaling the projects allows for a uniform comparison of high and low cost investments. For example, when two different projects have NPV's of $1M and $50k, ranking them is difficult because the NPV is just one of the project's many financial metrics. However, expressing NPV as a percentage of the total project cost allows for a more accurate comparison when ranking separate projects. Viewing NPV as a percentage of total cost provides more insight into the monetary picture of a project than NPV as a stand-alone metric, thus

giving more fidelity to the analysis. Furthermore, it allows the user to objectively compare a project costing millions of dollars to one that costs thousands.

Using financial data from three previously approved NSAM energy projects, we developed a Likert scale for the NPV/TC metric. The small sample size of three projects is a limitation discussed in the Conclusion chapter. Using the financial information available, we calculated the NPV/TC for each project, and then found the average NPV/TC along with the standard deviation of the data set. The average NPV/TC is 50.49% with a standard deviation of 52.87%. See Table 4 for data used for calculations.

Table 4. NSAM Energy Projects

	NPV	total cost	eroi	percentage of NPV
LED	$ 3,078,322.00	$ 2,778,456.00	1.44	110.79%
HVAC in glasgow	$ 65,344.00	$ 540,000.00	1.47	12.10%
HVAC in Watkins	$ 239,867.00	$ 839,000.00	1.54	28.59%
	data average	50.49%		
	data Std Dev	52.87%		

Adapted from Naval Support Activity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet]. Department of Defense, Naval Support Acitivity Monterey Energy Office. (2015b). *Rm12-3932 eroi v2 NSAM b304 b305 hvac 07–14-2015* [unpublished Excel spreadsheet]. Department of Defense unpublished & Naval Support Acitivity Monterey Energy Office. (2015c). *Rm12 3933 rme b246 fy15 eroi 07–01-2015* [unpublished Excel spreadsheet].

As shown in Table 5, a score of three on the Likert scale represents the average NPV/TC calculated from NSAM data. Each standard deviation increases or decreases the Likert scale value by one.

Table 5. NPV/Total Cost Scoring Scale

Score	Cost
Metric	NPV/Total Cost
0	-51% and below
1	(-1)-(-50%)
2	0-49%
3	50-99%
4	100-149%
5	150% and above

To calculate NPV/TC, perform the following steps:

1. Calculate the net present value (NPV) of project. Use estimates of initial capital cost, Operations and Maintenance costs, savings realized in energy cost and other factors of costs and savings that are achieved from the project. See Appendix A for example.

2. Divide calculated NPV from step one by the total cost of project. Assign a value from the Likert scale in Table 5 based on results.

4. Policy

The policy score is calculated against the following five energy objectives: (the first four are DOD's standard and the last is a DON objective:

1. The Energy Independence and Security Act (EISA) of 2007, which states that the DOD will reduce energy intensity relative to FY 2003 baseline.

2. Energy Policy Act of 2005 directs DOD to consume more electric energy from renewable sources.

3. Title 10 U.S.C. 2911(e) directs DOD to produce or procure more energy from renewable sources.

4. Executive Order 13423 requires DOD to reduce potable water intensity relative to FY 2007 baseline (Office of the Assistant Secretary of Defense (Energy, Installations, and Environment), 2015).

5. "Increase Alternative Energy Ashore. By 2020, DON will produce at least 50% of shore based energy requirements from alternative sources; 50% of DON installations will be net-zero" (Department of the Navy, 2012).

When scoring each attribute, energy planners will assess whether or not the project complies with the objective. If the project supports the objective and assists in meeting the criteria, the attribute will receive a 1. If the project does not support the

objective's criteria, it will be scored a 0. Therefore, the total possible score for the policy category is a six if the project supports all of the objectives.

F. CONCLUSIONS

Given the increased visibility of energy consumption and the trend toward renewables in today's fiscally constrained environment, energy planners face complex problems and overwhelming options requiring a variety of approaches before reaching a conclusion. Ultimately, the decision to approve or reject an energy project must be justified and supported with a logical and sequential decision making process. MAUA theory and the decision-making model developed for this project, provide a framework that considers quantitative data such as cost and savings over time, and qualitative data such as price volatility of fossil fuels and the storage ability of an energy project. The model is flexible and easily adaptable by modifying the weights of each category based on perceived value as well as adding and subtracting attributes of each category. Ultimately, the new decision model is a more comprehensive tool than the status quo.

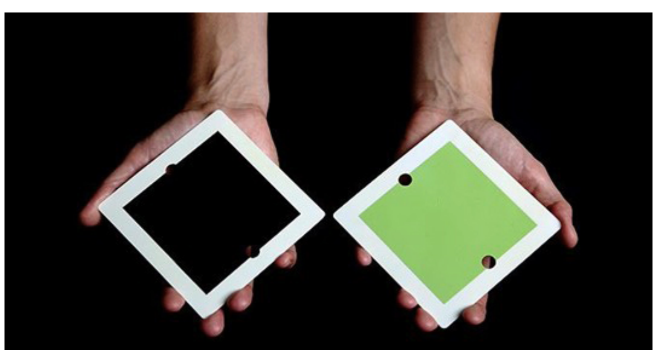
IV. DATA ANALYSIS

To validate the model developed for this project, we collected and analyzed data on an alternative energy generation project known as the Bloom Box. The Bloom Box, explained in detail below, provides reliable power independent of the commercial grid, which ultimately increases energy security through reduced risk and increased resiliency. The Bloom Box was analyzed utilizing the current energy investment tool, eROI, and then again with the energy decision model developed for this project. Finally, the outcomes of the Bloom Box projected from each model are compared and contrasted.

A. BLOOM BOX BACKGROUND

According to Bloom Energy, a Bloom Energy Server, commonly referred to as a Bloom Box, is a solid oxide fuel cell capable of providing electricity in place of traditional generation via the commercial grid. Each fuel cell consists of a disc made from processed beach sand that has been ground up and pressed into a ceramic, card-like object. The fuel cell card, shown in Figure 9, is then coated on one side with Bloom Energy's specialized green ink and the opposite side with different specialized black ink This process is referred to as powder to power by Bloom CEO and Co-founder K.R. Sridhar (loadevery, 2010).

Figure 9. Bloom Box Fuel Cell



Source: Buchanan, M. (2010, February 24). *Giz explains: Fuel cells and Bloom Energy's miracle box*. Retrieved November 28, 2015, from Gizmodo: http://gizmodo.com/5479460/giz-explains-fuel-cells-and-bloom-energys-miracle-box

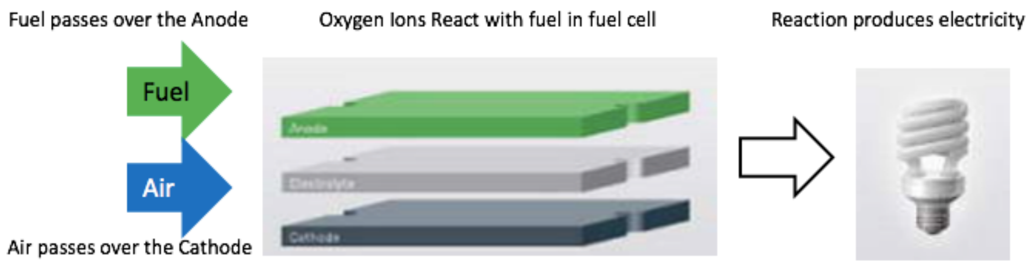
Independently, the fuel cells produce enough energy to power one light bulb or approximately 25 watts, which is not a practical amount of power; however, when combined and stacked to form a server or a system, as shown in Figure 10, their capacity increases exponentially. While the capability of a Bloom Box depends on a number of demand and usage factors, a 2010 report from *Gizmodo*, estimates that one 100kw server has the capacity to power a 30,000 sq. ft. office building or 100 homes (Buchanan, 2010). According to a Bloom Energy (2010) press release, a server is "the size of an average parking space," though research and development has led to decreased sizes as the kilowatt per hour capacity increases.

Figure 10. Fuel Cell to Solution Process

Adapted from Buchanan, M. (2010, February 24). *Giz explains: Fuel cells and Bloom Energy's miracle box*. Retrieved November 28, 2015, from Gizmodo: http://gizmodo.com/5479460/giz-explains-fuel-cells-and-bloom-energys-miracle-box

As shown in Figure 11, the Bloom Box functions by pumping oxygen in on one side of the card and a fuel source to the other. The two then combine within the cell producing a chemical reaction that produces electricity. The fuel source used within these cells varies depending on the customer and according to K.R. Sridhar, can be fossil fuels such as natural gas, renewable fuels such as landfill gas, to biofuels or solar. This allows the customer to tailor his or her Bloom Box to fit their best needs, both economically and financially.

Figure 11. Bloom Energy Server Fuel Cell



Adapted from Patil, V., & Chindhi, P. (n.d.). Bloom Energy technology. *IOSR Journal of Electronics and Communication Engineering, 6*(66), pp. 1–6. Retrieved from http://iosrjournals.org/iosr-jece/papers/sicete-volume6/66.pdf

A report, *Bloom Energy Technology*, published by the *Journal of Electronics and Communication Engineering* estimates a 200kw server to cost from $700,000 to $800,000. The large initial capital requirement has limited expansion in the consumer market; however according to Bloom Energy's website, companies such as FedEx, Walmart, and Target are commercial customers.

DOD could conceivably invest in a Bloom Box server or system on a test basis to experience the cost savings and experiment with alternative generation as a primary and/or backup source of power. The risks associated with the commercial grid decrease significantly and having a localized, on-site generation source provides lays the groundwork for a resilient infrastructure. Since the Bloom Box has an immediate impact on risk and resiliency, it is a useful project to demonstrate the model developed for this research.

B. BLOOM BOX EVALUATION UNDER EROI

We analyzed the Bloom Box in order to demonstrate a potential outcome and decision regarding the investment quality according to eROI metrics. The following evaluation is a hypothetical situation where a 250kw Bloom Box is installed and supplies 100% of the power to the Dudley Knox Library, which has an unverified peak demand of 200kw. The library is a non-critical office building on the main campus of NSAM. The evaluation is organized consistently with the five eROI drivers: maximizing financial

benefits, minimizing shore energy consumption, providing reliable energy, compliance with regulatory and shareholders expectancies, and developing enabling infrastructure.

1. Maximizing Financial Benefits

eROI evaluates the financial benefits of a project according to three cost-related criteria: investment cost, energy savings or costs, and non-energy savings or costs.

a. Investment Cost

The investment cost section calculates the NPV of construction costs, planning, designing disposal and operation and maintenance. Construction costs are irrelevant for the Bloom Box since DOD will simply purchase the actual hardware. However, initial up-front capital required to purchase a Bloom Box is estimated at $800,000 per box for their most powerful server that produces 250kw of continuous power (Patil & Chindhi). This cost includes installation and a physical site to hold the hardware.

The next investment cost is a fuel source and as stated earlier, fuel sources can vary from fossil fuels to renewables, though natural gas is the most common. A report from The University of Chicago, found that a single Bloom Box "consumes natural gas at a rate of 661 cubic feet per hour" (Bassett, England, Li, Weinberger, & Wong). Since Bloom Box has a life expectancy of ten years, we collected data from the *U.S. Energy Information Administration* website, and calculated the average price of natural gas over the past decade, which is $8.19 per thousand cubic feet. Assuming the Dudley Knox Library requires continuous electricity for eight hours per day and five days per week, the monthly natural gas consumption is 105,760 cu. ft.

$$0.661\ cu.ft. \times 40\ hours\ per\ week \times 4\ weeks\ =\ 105{,}760\ cu.ft.\ per\ month$$

The cost of that consumption is approximately $866 per month, which equates to a $10,392 natural gas bill.

$$\frac{105{,}760\ cu.ft.\ per\ month}{1000}\ =\ 105.76 \times \$8.19\ per\ thousand\ cu.ft$$
$$=\ \$866\ per\ month \times 12\ months\ =\ \$10{,}392$$

b. Energy Savings or Cost

Energy savings or cost is calculated as the difference between the cost for electricity from the commercial grid and the cost of electricity for the Bloom Box. The report, *Bloom Energy Technology*, mentioned earlier in the chapter, calculates the Bloom Box energy cost as \$0.08 to \$0.09 per kwh (kilowatt hour) and \$0.13 to \$0.14 as the typical cost per kwh in California (p. 3). The net result is an average savings of \$0.045 per kwh, which equates to monthly savings \$1,800 and annual savings of \$21,600.

$$\begin{aligned} &\$0.045\ per\ kwh \times 250kwh \\ &\quad = \$11.25\ per\ hour \times 40\ hours\ per\ week \times 4\ weeks\ per\ month \\ &\quad = \$1{,}800 \times 12\ months\ =\ \$21{,}600 \end{aligned}$$

Using only energy cost savings, the payback period for one Bloom Box is over 37 years.

$$\frac{\$800{,}000\ initial\ cost}{\$21{,}600\ annual\ savings}\ =\ 37.03\ years$$

c. Non-Energy Savings or Cost

This section addresses dollars saved or spent on maintenance, staff employment, repairs or replacement to equipment, and any other recurring or non-recurring savings or costs. Once the Bloom Server is in place and fully operational, the yearly fixed maintenance cost is approximately \$264 (Adams, Chowdhary, & Subbaiah, 2011) over the estimated lifespan of ten years. The cost of energy maintenance on DOD installations varies. On the main campus of NSAM, the Navy owns and maintains the grid. At other bases, the local utility owns the wires up to the point of entry to each building, and each building has a utility-owned meter. Lastly, some bases are a mixture of the two ownership variations. Estimates for energy maintenance at NSAM is \$0.02 per kwh, which means that the estimated annual maintenance cost at a building that draws 200kw is \$7,680.

$$\begin{aligned} &\$0.02\ kwh \times 200kw\ = \$4\ per\ hour \text{ x } 40\ hours\ per\ week \text{ x } 4\ weeks\ per\ month \\ &\quad = \$640\ per\ month \text{ x } 12\ months\ =\ \$7{,}680 \end{aligned}$$

The net result is an annual maintenance savings of \$7,416.

$$\$7{,}680 - \$264 = \$7{,}416$$

d. NPV

The last step of the investment costs section is calculating the NPV. The Office of Management and Budget released a memorandum in January 2015 that establishes guidelines and discount rates for benefit-cost analysis of federal programs. The real interest rate for a ten-year investment is 0.9%. Using the costs identified above, one Bloom Box has an NPV of -\$600,135. See Appendix for calculations.

2. Minimizing Shore Energy Consumption

An efficient energy generation method limits greenhouse gas emissions and ultimately minimizes shore energy consumption. This section calculates a net gain or less on the greenhouse gas emissions produced by the projected fuel source (natural gas) for the Bloom Box vs. the commercial grid. To score this driver, eROI compares the electricity produced by the Bloom Box to the emission it would had taken to produce the same amount of energy conventionally, and is measured by its output of CO_2 (carbon dioxide), CH_4 (methane), and NO_2 (nitrous dioxide). Bloom Box claims their 250kw server emits between 735 lbs. and 849 lbs. of CO_2 per megawatt hour (MWh) (Bloom Energy). The average of that range comes out to 792 lbs. per MWh (or 158.4lbs. per kwh), approximately half of what the commercial grid emits, as shown in Figure 12. At that rate, a Bloom Box powering a building drawing a continuous 200kw for 40 hours per week and four weeks per month emits approximately 5,068,800 lbs. of CO_2 per month, while the annual emission is 60,825,600 lbs.

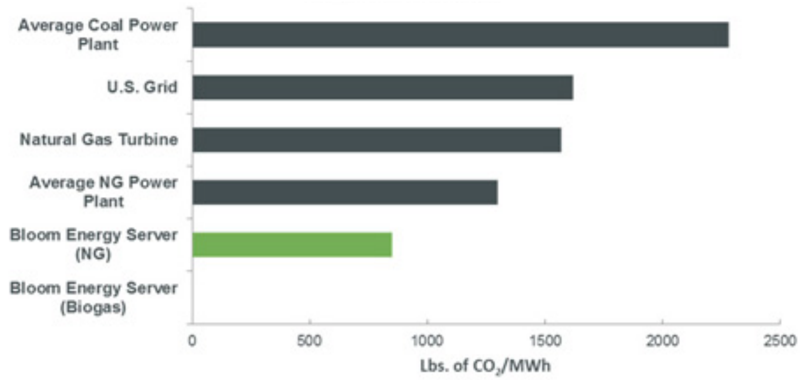
$$158.4\ lbs. of\ CO_2\ per\ kwh \times 200kw = 31{,}680\ lbs\ of\ CO_2$$

$$31{,}680\ lbs\ of\ CO_2 \times 40\ hours\ per\ week \times 4\ weeks$$
$$= 5{,}068{,}800\ lbs. of\ CO_2\ per\ month$$

$$5{,}068{,}800\ lbs. CO_2\ per\ month \times 12\ months = 60{,}825{,}600\ lbs. of\ CO_2$$

Since the commercial grid produces approximately double the amount of emissions, we estimate the net CO_2 emission reduction to be 60,825,600 lbs. Over the expected 10-year life span of a Bloom Box, over 608 million lbs. of CO_2 emission is eliminated.

Figure 12. CO_2 Emissions



Source: Bloom Energy. (n.d.). *Clean energy: Bloom Energy delivers better electrons*. Retrieved November 29, 2015, from http://www.bloomenergy.com/clean-energy/

Though eROI also accounts for CH_4 and NO_2 emissions, Bloom Box CH_4 and NO_2 data was not available for this project. However, in each of the three eROI evaluations that we analyzed for this project, CO_2 accounted for over 99% of total emissions, making CH_4 + NO_2 emissions account for less than 1%. While that 1% is not considered negligible, capturing 99% of the total emissions still describes a reliable and accurate picture of the emissions for Bloom Box.

3. Provide Reliable Energy

While the first two eROI drivers use quantitative data, providing reliable energy is both a quantitative and qualitative assessment. The evaluation is based on a project's ability to provide reliable energy to critical facilities. The assessment is measured in terms of a mission dependency index (MDI), which prioritizes mission-critical facilities, frequency and duration of outages, the availability of backup power, and the project's reliance on energy to conduct mission-essential tasks. The Bloom Box was scored according to the following five questions as per the eROI methodology:

1. How many mission critical facilities will receive new backup power as a result of this project? **Zero, thus the score for this question is 0.** The Bloom Box is employed as a primary power source and NSAM does not utilize backup generation.

2. Enter the MDI score of the facility. **We assess that the MDI score for the NSAM Dudley Knox Library is a 65**. Table 6 represents the MDI scoring scale. The NSAM mission would continue if the library were not operational, therefore the facility is not mission critical. However, the Naval Postgraduate School would be significantly less capable of efficient education without full power to the library.

Table 6. Mission Dependency Index Scoring Scale

70–100 Points	Mission Critical Facilities
31–69 Points	Mission Dependent Facilities
0–30 Points	Mission Independent Facilities

Adapted from Mission Dependency Index. (n.d.) Retrieved from http://www.assetinsights.net/Glossary/G_Mission_Dependency_Index.html

3. Based on the average number of outages per year and their duration, how would you characterize the facility’s susceptibility to outages? In the past year, Dudley Knox Library experienced one outage lasting for less than six hours. **The score for this question is a 2**. Figure 13 represents the scoring scale for this question.

Figure 13. Susceptibility Scoring Scale

1 = Outages do not tend to occur (on average less than 1 time every 2 years) and are short in duration (less than 6 hours on average)
2 = Outages occur infrequently (on average between 1 and 3 times every 2 years) and are short in duration (less than 6 hours on average)
3 = Outages occur infrequently (on average between 1 and 3 times every 2 years), but are long in duration (more than 6 hours on average) OR Outages occur frequently (on average more than 3 times every 2 years, but are short in duration (less than 6 hours on average)
4 = Outages occur frequently (on average more than 3 times every 2 years) and are prolonged in duration (greater than 6 hours average)

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015*[unpubished Excel spreadsheet].

4. Does the critical infrastructure currently have backup power available? The library does not have backup power, therefore **scores a 0.** Figure 14 represents the scoring scale for this question.

Figure 14. Backup Power Availability Scoring Scale

0 = No back up power is available
1 = There is a portable generator, which can be moved to the location and started within 24 hours of the outage.
2 = It has a dedicated generator, which provides backup power with a conversion startup time that will take one to several minutes.
3 = It has a dedicated UPS and a dedicated generator that provides instantaneous backup power
(Note: A dedicated backup power source may provide power to multiple facilities.)

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015*[unpublished Excel spreadsheet].

5. Considering the level of current backup power indicated in question 4, what percentage of the critical infrastructure functions could you continue to perform during an outage, in any? Since NSAM does not employ backup generation, 0% of critical functions could be performed during an outage and therefore, **scores a 0.** Figure 15 represents the scoring scale for this question.

Figure 15. Critical Infrastructure Scoring Scale

1 = None, critical functions cannot be performed during a power outage
2 = Up to 10% of the critical function could be performed during a power outage
3 = Between 11% and 50% of the critical function could be performed during a power outage
4 = Between 51% and 99% of the critical function could be performed during a power outage
5 = All 100% of the critical function could be performed during a power outage

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015*[unpublished Excel spreadsheet].

4. Regulatory Compliance and Shareholder Expectations

eROI measures regulatory compliance in accordance with the following mandates:

- Energy Independence and Security Act (EISA) of 2007
- Executive Order 13423 and 13514
- Energy Policy Act of 2005
- National Defense Authorization Act (NDAA) of 2005

The list is similar to the DOD standard list of mandates found in Table 1 of Chapter 1, with the exception of the NDAA. "As per the FY 2012 NDAA the DON has

an additional requirement to meter Navy piers to accurately measure the energy consumption of naval vessels in port" (Office of the Assistant Secretary of Defense (Energy, Installations, and Environment), 2015). The shareholder's expectation piece of this driver is addressed in questions 2–4. The Bloom Box was scored according to the following four questions as per the eROI methodology:

1. Given the regulatory mandates above, Bloom Box complies with how many? We assess that Bloom Box complies with 2 mandates: the EISA since petroleum consumption is reduced and the EPA since the Bloom Box includes a meter to measure natural gas consumption. **Bloom Box receives a score of 2** as per the scoring scale in Figure 16.

Figure 16. Regulatory Compliance Scoring Scale

Scoring Scale (Treats Executive Order 13423 and 13514 as one)
4 = address or contribute to all four mandates
3 = address or contribute to three mandates
2 = address or contribute to two mandates
1 = address or contribute to one mandate
0 = address or contribute to none of the mandates

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet].

2. Public Perception: Will this project showcase to the public that the Navy is investing in renewable energy that will yield social policy benefits. **We score the Bloom Box a 3** because the server is perceived as alternative energy and is advertised as a more eco-friendly generation solution as compared to the commercial grid. The scoring scale for this question is shown in Figure 17.

Figure 17. Public Perception Scoring Scale

3 = this project will receive extremely favorable national or international media coverage
2 = this project will receive moderately favorable regional media coverage
1 = this project will receive only minor favorable local media coverage
0 = this project will receive no media coverage

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet].

3. The Navy's quality of service goals are: having a work environment that contributes to personal and professional growth, high job satisfaction,

ongoing professional growth, high-quality training, education, and personal recognition. How will this project impact the Navy's quality of service goals? **The Bloom Box scores a 1** in this category because quality of service will likely increase due to the elimination of commercial grid outages. The scoring scale is shown in Figure 18.

Figure 18. Quality of Service Scoring Scale

3 = Quality of Service will be positively impacted to a significant degree
2 = Quality of Service will be positively impacted to a moderate degree
1 = Quality of Service will be positively impacted to a modest but noticeable degree
0 = this project will not have a noticeable impact on Quality of Service
-1 = Quality of Service will be negatively impacted to a modest but noticeable degree
-2 = Quality of Service will be negatively impacted to a moderate degree
-3 = Quality of Service will be negatively impacted to a significant degree

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet].

4. The impact this project will have on quality of service will affect how many people in the Navy? Since the Bloom Box life span is ten years, it potentially impacts thousands of personnel that will use the Dudley Know Library over that time period. **Bloom Box receives a 5** for this question. The scoring scale for this question is shown in Figure 19.

Figure 19. Quality of Service Affects Scoring Scale

6 = greater than 100,001 Active, Reserve and DoN Civilians
5 = between 10,001 and 100,000
4 = between 1,001 and 10,000
3 = between 101 and 1,000
2 = between 11 and 100
1 = between 1 and 10

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet].

5. Develop Enabling Infrastructure

The Develop Enabling Infrastructure driver refers to the Navy's objective of developing infrastructure that will enable a comprehensive and reliable grid in the future. The following four questions used for scoring are purely subjective but assist in

collecting data regarding the project's contribution toward a reliable energy infrastructure.

1. How will this project impact the Navy's data and information regarding energy demand and supply? **Bloom Box scores a 3** for this question because the server provides significant new technology, information, and infrastructure. The scoring scale is shown in Figure 20.

Figure 20. Energy Demand and Supply Data Scoring Scale

3 = The Navy will experience a comprehensive improvement in its data and information about energy demand and supply. Significant new information or significant new technology/infrastructure will be created with a major scope of applicability including information provided through onsite energy audits. The new information generated by this project will provide Navy with all of the following:
- comprehensive historic and projected information about energy usage
- historic and real-time electricity outage and disruption information
- real-time monitoring information about electricity usage at the end user level
- historic and real-time and project information on electricity production within the facility, if electricity is produced on base
- presentation of information on management that are comprehensive, easy to understand, insightful, decision oriented and timely
- high-quality, accurate, and auditable data that can be maintained, secured and integrated
- potential for significant future energy savings or cost avoidance
- application to a large fraction of the Navy's facilities
- ability to share information about critical energy or about lessons learned between bases and geographic regions

2 = Navy will experience a **moderate** improvement to its data and information about energy demand and supply. New information or technology/technical infrastructure will be created with a **moderate** scope of applicability and with most (but not all) of the characteristics needed to qualify for a score of 3. As a consequence Navy will experience at least a **moderate** positive impact on at least **two** of the strategic objectives listed for a score of 3, and will apply to **all assets** within **at least one facility**.

1 = Navy will experience a **minor** improvement to its data and information about energy demand and supply. New information or technology/technical infrastructure will be created with a **minor** scope of applicability and with most (but not all) of the characteristics needed to qualify for a score of 3. As a consequence Navy will experience at last a **minor** positive impact on at least one of the strategic objectives listed for a score of 3, and will apply to **at least one facility.**

0 = **No Impact**

From Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [excel spreadsheet]. Department of Defense unpublished

2. How will this project impact the development of a flexible energy infrastructure at Navy installations? **Bloom Box receives a 2** for this question based on its ability to stabilize energy delivery and reduce reliance on the fragile commercial grid. The scoring scale is shown in Figure 21.

Figure 21. Flexible Energy Infrastructure Scoring Scale

3 = The Navy will experience a comprehensive improvement in its data and information about energy demand and supply. Significant new information or significant new technology/infrastructure will be created with a major scope of applicability including information provided through onsite energy audits. The new information generated by this project will provide Navy with all of the following:

- comprehensive historic and projected information about energy usage
- historic and real-time electricity outage and disruption information
- real-time monitoring information about electricity usage at the end user level
- historic and real-time and project information on electricity production within the facility, if electricity is produced on base
- presentation of information on management that are comprehensive, easy to understand, insightful, decision oriented and timely
- high-quality, accurate, and auditable data that can be maintained, secured and integrated
- potential for significant future energy savings or cost avoidance
- application to a large fraction of the Navy's facilities
- ability to share information about critical energy or about lessons learned between bases and geographic regions

2 = Navy will experience a **moderate** improvement to its data and information about energy demand and supply. New information or technology/technical infrastructure will be created with a **moderate** scope of applicability and with most (but not all) of the characteristics needed to qualify for a score of 3. As a consequence Navy will experience at least a **moderate** positive impact on at least **two** of the strategic objectives listed for a score of 3, and will apply to **all assets** within **at least one facility**.

1 = Navy will experience a **minor** improvement to its data and information about energy demand and supply. New information or technology/technical infrastructure will be created with a **minor** scope of applicability and with most (but not all) of the characteristics needed to qualify for a score of 3. As a consequence Navy will experience at last a **minor** positive impact on at least one of the strategic objectives listed for a score of 3, and will apply to **at least one facility**.

0 = **No Impact**

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet].

3. How will this project impact the Navy's ability to demonstrate new energy technology adoption that enables energy independence? Since the Bloom Box installation is the first of its kind on a Navy installation, **it scores a 3** as the server promotes learning, validation of new technologies, and demonstrates a leading role among DOD organizations in alternative energy generation. The scoring scale is shown in Figure 22.

Figure 22. New Energy Technology Scoring Scale

Scoring Scale

3 = The Navy will experience a **comprehensive** learning and validation of the applicability of new energy technologies for deployment within the Navy through a successful implementation and demonstration initiative. This project will provide a **significant** impetus for the rollout of new energy technologies. Without this project, the learning, validation, and impetus for rolling out this new technology would not occur.

2 = The Navy will experience a **moderate** learning and validation of the applicability of new energy technologies for deployment within the Navy through a successful implementation and demonstration initiative. This project will provide a **moderate** impetus for the rollout of new energy technologies. Without this project, the learning, validation, and impetus for rolling out this new technology would not occur.

1 = The Navy will experience a **limited** learning and validation of the applicability of new energy technologies for deployment within the Navy through a successful implementation and demonstration initiative. This project will provide a **minor** impetus for the rollout of new energy technologies. Without this project, the learning, validation, and impetus for rolling out this new technology would not occur.

0 = This project **does not** provide any "demonstration value".

Source: Naval Support Acitivity Monterey Energy Office. (2015a). *P852 v.21 eroi NSAM fy18 lighting ECIP_03-03-2015* [unpublished Excel spreadsheet].

4. This project will be applicable at what percentage of current, operating Navy installations? The Bloom Box is not operating on any other Navy installations and is therefore **scored at a 0%.**

C. RESULTS

A limitation of this project (discussed in detail in the last chapter) is the lack of a working copy of the eROI spreadsheet. Since "read only" copies were available for this project, an actual eROI score or B/C ratio is not available for the Bloom Box project. However, since the eROI tool places such a high value on the cost metrics, Bloom Box would receive a very low overall score due to the extremely poor NPV and the 37-year payback period. Bloom Box scored well on the "Develop Enabling Infrastructure" and "Minimize Shore Energy Consumption" drivers; however, because those drivers are weighted at just 9% and 13% respectively, the favorable scores do not leave the Bloom Box project in good standing due to the over valuation of the cost metrics. An alternative energy generation project such as Bloom Box provides the energy security and independence that Secretary Mabus said is necessary "for our installations to be able to sustain critical missions in the face of ever-rising uncertainty regarding their electrical power" (Department of the Navy, 2010). Yet, the Bloom Box, or any other project with a poor NPV would not be considered despite making innovative strides toward energy security and independence.

D. BLOOM BOX EVALUATION UNDER NEW MODEL

As explained earlier, the model developed for this project functions differently than eROI. Each energy category consists of attributes that receive a score from zero to five (or zero to one for the policy category). The following is a breakdown of how the Bloom Box evaluation using our model with the scoring scale shown in Table 7.

Table 7. Scoring Criteria and Metrics

Score	Risk	Resiliency	Cost	Policy
Metric	Does the project mitigate risk?	Is resiliency increased?	NPV/Total Cost	How many DOD/DON policies are supported by the project?
0	Risk is adversely effected	Resiliency is adversely effected	-51% and below	Supports 0
1	Risk is not effected	Resiliency is not effected	(-1)-(-50%)	Supports 1
2	slight improvement	slight improvement	0-49%	Supports 2
3	moderate improvement	moderate improvement	50-99%	Supports 3
4	significant improvement	significant improvement	100-149%	Supports 4
5	extreme improvement	extreme improvement	150% and above	Supports 5

1. Risk

a. Natural Disasters

NSAM is located on the Central California Coast where earthquake and tsunami disasters pose a realistic threat. Since earthquakes occur regularly throughout this region, the probability of occurrence is high but the most likely scenario is limited damage, if any. A primary risk from a natural disaster is disruption of natural gas delivery because the Bloom Box cannot function without a continuous supply. The Bloom Box is a more durable infrastructure than the commercial grid because it is smaller and can be installed on elevated ground with sufficient drainage to reduce the risk of outage from flooding or storm surge. Most commercial grids are large, and more prone to outage from high winds or flooding. Additionally, less electric wiring is required to run from the server to the library and the wiring that is necessary is underground so there is a reduced risk of damage from a disaster. **Score: 3.5.**

b. Terrorist Attack/Intelligent Adversary

Since the Dudley Knox Library is not a mission critical facility, and this Bloom Box project powers just a single building, an attack is less likely than an attack on a large outstation that supplies critical power to a larger population. The Bloom Box is installed on a secure DOD installation, so security is significantly enhanced over the commercial grid since most outstations are located in remote areas with a minimal security presence. Therefore, access to the actual server is limited. Furthermore, the Bloom Box is essentially a "plug and play" server, so repairing a damaged unit takes much less time than repairing or replacing a damaged transformer (which can take months). Risk of a deliberate attack is significantly decreased with a Bloom Box installed. **Score: 4.**

c. Commercial Grid Reliance

For this project, the Bloom Box supplies 100% of the power to the Dudley Knox Library therefore, it is independent of the commercial grid. The server is not susceptible to grid overload or brownout/blackout. Both energy security and independence are enhanced due to reduced risk of commercial grid reliance. **Score: 5.**

d. Fossil Fuel Consumption

Though the Bloom Box can be powered with renewable energy such as solar or wind, for this project, it is 100% reliant on natural gas. Therefore, it is exposed to market price volatility associated with supply shortages and potential delivery issues. However, as noted earlier, the Bloom Box is almost twice as efficient operating off of natural gas as compared to the grid. Therefore, fossil fuel consumption sees a risk reduction. **Score: 3.**

2. Resiliency

a. Localized Generation

The Bloom Box has the ability to generate power locally despite its reliance on a continuous natural gas supply and therefore, improves upon the alternative of relying on an off-site grid. This particular server is capable of providing 250kw of continuous power to the library, which has peak demand of 200kw. The result of a greater supply than peak demand is risk reduction and increased resiliency. The Bloom Box is capable of

providing power during weather conditions outside the norm, whereas a non-local generation site is more susceptible to outages. The localized generation ability of the Bloom Box significantly enhances resiliency over the grid. **Score: 4.**

b. Conservation

In theory, installing a Bloom Box has little to no effect on demand as it does not encourage energy reduction through decreased usage. However, because the Bloom Box consumes natural gas more efficiently than the grid and other generators, conservation is moderately improved. **Score: 3**.

c. Priority Distribution

As of the date of this project, Bloom Box servers do not have the ability to control which nodes receive power. For this project, the Bloom Box is powering a single building and does not have an option to re-route power. **Score: 1.**

d. Storage Ability

The Bloom Box does not have the capacity to store excess power nor a reserve fuel source. Installing the Bloom Box results in no change from the grid regarding energy storage. **Score: 1.**

e. Repairability

As mentioned earlier, repairing or replacing parts on the commercial grid can take months. Often, parts are manufactured as requested because demand is so low. While on-site repair teams are unlikely for this project because Bloom Box is a commercial product installed on a DOD installation, repair parts are more readily available, which significantly reduces down time. Additionally, the Bloom Energy Company is incentivized to replace or repair parts as quickly as possible since it is an emerging technology that is seeking market approval and validation. The commercial grid is a state owned infrastructure and is not motivated in the same way as a private entity. Also, replacing parts is a one-for-one exchange so minimal maintenance time is required for repair. **Score: 3.5.**

f. Adaptability

The Bloom Box is marketed as a flexible energy solution because of its ability to provide power using renewable sources or fossil fuels. This feature provides an installation with options, should the Bloom Box be re-purposed for another project in the future. Also, the server plugs right into existing infrastructure. Rewiring the library or changing fuse box and breaker locations is not necessary. The Bloom Box is a significant improvement over the adaptability capacity of the grid. **Score: 4.**

3. Cost

This model calculates the cost metric as a percentage of NPV/Total Project Cost. The NPV calculated for the Bloom Box is -$600,135 as identified under the Bloom Box evaluation using eROI earlier in the chapter. Expressed as a percentage of total project cost, Bloom Box yields a cost metric of -75% and thus earns a **score of 0.** See Appendix for calculations.

4. Policy

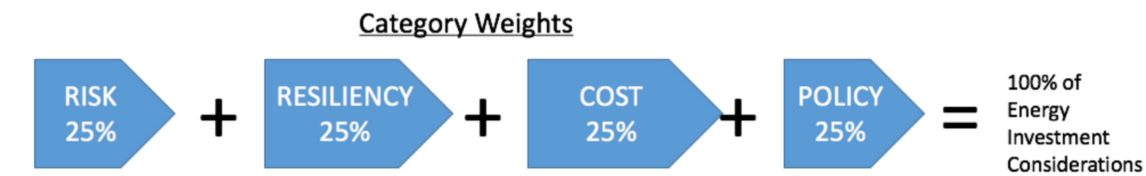
The policy category of this model is scored differently than the three previous categories. Rather than a zero to five scale, if the project supports the policy, the score is a one, zero otherwise. The Bloom Box is scored as follows:

1. The Energy Independence and Security Act of 2007. Bloom Box supports this policy as the project reduces petroleum consumption. **Score: 1.**
2. Energy Policy Act of 2005. Bloom Box supports this policy due to the local meter installed for on-site monitoring of consumption. **Score: 1.**
3. Title 10 U.S.C. 2911(e). Bloom Box does not support this policy as this particular server does not utilize a renewable fuel source. **Score: 0.**
4. Executive Order 13423. According to the Bloom Energy website, the server uses “no water during normal operation beyond a 240-gallon injection at start up.” A 250kw Bloom server could save up to 21.5 million gallons annually compared to the commercial grid (Bloom Energy). Therefore, the Bloom Box supports this order and receives a **score: 1.**
5. DON initiative to increase alternative energy ashore. Bloom Box supports this mandate since it is an alternative energy generation project. **Score: 1.**

E. RESULTS

The result of the Bloom Box evaluation using the new model is a score of 53.2% out of a maximum score of 100% as show in Figure 23. While this may seem like a poor score, standards for comparison do not yet exist. Bloom Box scored well in the policy, risk, and resiliency categories, but poorly according to the cost metrics. However, since each category is weighted equally, cost does not account for the majority of the model as with eROI. The project scored well because the model does not favor one category over another.

Figure 23. Bloom Box Results

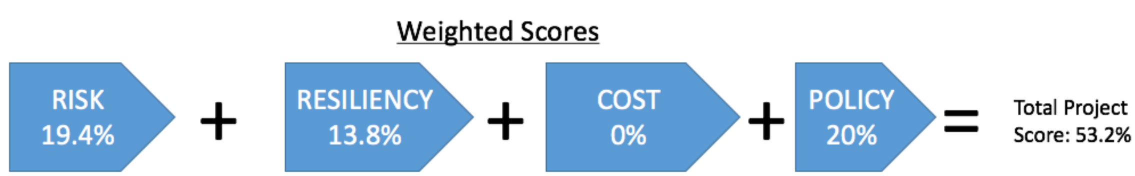


Attribute	Score 0-5
Natural Disasters	3.5
Terrorist Attack	4
Commercial Grid Reliance	5
Fossil Fuel Consumption	3
Total Risk Score	15.5/20

Attribute	Score 0-5
Localized Generation	4
Conservation	3
Priority Distribution	1
Storage Ability	1
Repairability	3.5
Adaptability	4
Total Resiliency Score	16.5/30

Attribute	Score 0-5
NPV / Total Project Cost	0

Attribute	Score 0 or 1
EISA (2007)	1
EPA (2005)	1
Title 10 U.S.C. 2911(e)	0
EO 13423	1
DON Alternative Ashore	1
Total Policy Score	4/5



The flexibility of this model allows energy planners to adjust category weights to experiment with outcomes. For example, a fiscally constrained environment may dictate that cost metrics will carry the majority of the weight in the model. Conversely, risk and resiliency receive stronger consideration and carry higher value when a project is located in a high-risk environment. Since the risk and resilience metrics are subjective, the category weights should be modified in an experimental fashion in order to see how outcomes and project selection might change with perceived value. For example, Figure

24 shows the same Bloom Box project evaluated with different category weights and thus, a different final score.

Figure 24. Modified Bloom Box Results

Category Weights

RISK 35% + RESILIENCY 35% + COST 15% + POLICY 15% = 100% of Energy Investment Considerations

Attribute	Score 0-5
Natural Disasters	3.5
Terrorist Attack	4
Commercial Grid Reliance	5
Fossil Fuel Consumption	3
Total Risk Score	15.5/20

Attribute	Score 0-5
Localized Generation	4
Conservation	3
Priority Distribution	1
Storage Ability	1
Repairability	3.5
Adaptability	4
Total Resiliency Score	16.5/30

Attribute	Score 0-5
NPV / Total Project Cost	0

Attribute	Score 0 or 1
EISA (2007)	1
EPA (2005)	1
Title 10 U.S.C. 2911(e)	0
EO 13423	1
DON Alternative Ashore	1
Total Policy Score	4/5

Weighted Scores

RISK 27.1% + RESILIENCY 19.3% + COST 0% + POLICY 12% = Total Project Score: 58.4%

With risk and resilience now weighted at 35% each, and cost and policy at 15% each, the total project score increases by over 5%. This may not seem like a significant difference but the purpose of manipulating the model is not to produce a more favorable or preferred outcome, but to make energy planners realize that risk and resiliency are important factors to consider when making energy investments. When the categories are perceived to have more value, they will affect the outcome of energy project prioritization and selection.

F. COMPARISON OF THE BLOOM BOX UNDER THE TWO DIFFERENT MODELS

While the two models evaluate many of the same metrics and factors, their outcomes are different. Under eROI, financial metrics dominate with a 39% value and as a result, the Bloom Box scores poorly because of the significant initial capital required to purchase the server and the considerably long payback period of over 37 years. Under the new model, financial metrics are perceived to have a more equivalent value to risk and resiliency. Predictably, the Bloom Box project receives better scores with all categories on an equal playing field. Under eROI, Bloom Box would receive a very low B/C ratio

placing it at the bottom of the priority list and may never receive any funding. However, when evaluated under the new model, energy planners realize that the Bloom Box provides reliable, independent and, secure energy.

V. CONCLUSION

A. LIMITATIONS

We experienced a number of limitations regarding the development of the new model and the analysis of eROI. The first limitation is a small sample size of data. For the cost category or our model, we developed a scoring scale using the NPV's of three past NSAM energy projects. A sample size of just three projects is not enough data to determine a realistic range, mean, or standard deviation of net present values. In FY 2014, the Navy evaluated at least 169 energy projects using eROI. Ideally, the data to validate a model includes as many past energy projects as possible, but a sufficient sample size of that population is at least 10% or 17 projects.

Another limitation is a working copy of the eROI spreadsheet. In order to evaluate the Bloom Box effectively using the eROI tool, we needed to input Bloom Box data into a working spreadsheet. Since we only had access to a "read only" version, we were unable to obtain an actual eROI score or B/C ratio and as a result, our assessment of the Bloom Box was based largely off of assumptions and subjective interpretations of the eROI questions.

eROI is further limited because we do not know how the B/C score is actually calculated. The questions and required data is visible on each tab of the spreadsheet but the actual calculations are hidden. Understanding the eROI scoring process will allow the user to obtain a score even with a "read only" version of the tool.

A goal for this project was to develop a method to quantify intangible factors related to energy risk and resiliency. Though that goal was attained through employing a Likert scoring scale, a potential constraint of the model is the subjective inputs for the risk and resiliency categories. Unlike the other two energy categories of cost and policy, risk and resiliency is scored using mostly qualitative data and is therefore open to interpretation. Consequently, a single project or a range of projects may receive a wide variation of results depending on the user's perceived value of risk and resiliency and their interpretation of the category attributes.

Furthermore, the adjustment of the category percentages allows the user to manipulate the model to yield a favorable outcome. We view the flexibility of the model as a positive aspect, though the user can easily devalue risk and resiliency while increasing the value of the cost and policy categories to produce the preferred outcome.

Finally, the model is currently limited due to its lack of validation. Since it is brand new and has been tested just one time for the research of this project using a small sample size, the model lacks fidelity and should be tested further to gain traction.

B. FURTHER RESEARCH

Further research is necessary to validate the model since it is newly developed and has been tested using only a theoretical project. The result of the Bloom Box evaluation conducted for this project is limited because the only alternative to compare the project against is the commercial grid. Ideally, a project should have two or more alternatives to allow for an equivalent comparison. Follow-on research should be focused on collecting relevant and current data on energy generation projects to be evaluated using the new model. Obtaining information on projects specific to energy generation is important because many energy projects have a negligible effect on risk and resiliency and therefore, would not be suitable to validate the model. For example, information on small-scale projects such as LED light bulb conversion or HVAC improvements is accessible but neither of those projects have an impact on risk or resiliency. If those projects were evaluated under the new model, the output would have little value as compared to an eROI evaluation. The new model is most valuable when evaluating projects that can significantly impact risk and resiliency such as alternative/renewable energy generation. We recommend follow-on research to incorporate such projects to further validate the new model. We hypothesize that the metrics and category attributes will need adjustments as the model gains fidelity.

Another research opportunity exists to test the model beyond the scope of individual energy projects. Energy planners and Commanders at Naval shore installations need a tool to evaluate their entire energy infrastructure. eROI falls short in fulfilling that requirement because it is specifically designed to evaluate a single project at a time. The

new model can be adapted to assess a complete energy infrastructure at an installation. For example, if the energy planners for NSAM wanted information on the efficiencies and shortfalls of the energy infrastructure at the Naval Postgraduate School, Monterey, the new model can accomplish that by interpreting the data collectively. The output of such an evaluation allows planners to identify where the installation is meeting requirements and falling short of energy mandates, which ultimately allows for efficient allocation of funding and other resources.

C. SUMMARY

Today's energy investment process lacks the inclusion of risk and resiliency factors necessary to provide energy security and independence. While cost metrics such as NPV cannot be ignored as the DOD adjusts to constrained budgets, the over reliance on an unstable commercial grid leaves shore installations with too much risk. The question for energy planners and leaders is, "What is an acceptable level of risk?" Since current energy decisions are not inclusive of a full scope of risk, that question remains unanswered. If cost must remain the primary consideration moving forward then the question becomes, "How much cost savings must a project generate to accept a higher level of risk and lower level of resiliency?"

The implied objective of the model is not necessarily to show that considering the full scope of risk and resiliency will always lead to a different decision, but rather to illustrate that under certain conditions the outcome will be different. As explained in the Data Analysis chapter, a project scores differently when the perceived value of cost, risk, resiliency, and policy vary.

The Navy perceives eROI as a comprehensive tool for energy investments, but as this project has shown, the model omits important factors of risk and resiliency, thus exposing shore installations to increased risk. Today, energy security is at the mercy of the national power grid. Partially to blame for this flaw is an over emphasis on cost metrics and an undervaluation of risk and resiliency. The model developed for this project improves upon the status quo and places the Navy closer to Secretary Mabus' goals of energy security and independence.

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APPENDIX. NPV CALCULATION

Bloom Box estimated cash inflow/outflow by year (FY16 Dollars)											
	0	1	2	3	4	5	6	7	8	9	10
Cash Outflows											
INVESTMENT	-$ 800,000										
fuel cost		-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394	-$ 10,394
maintenance cost		$ 7,416	$ 7,416	$ 7,416	$ 7,416	$ 7,416	$ 7,416	$ 7,416	$ 7,416	$ 7,416	$ 7,416
total	-$ 800,000	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978	-$ 2,978
Cash Inflows											
fuel savings (@.045)		$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400
	$ -	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400	$ 23,400
Net Cash flows	-$ 800,000	$ 20,422	$ 20,422	$ 20,422	$ 20,422	$ 20,422	$ 20,422	$ 20,422	$ 20,422	$ 20,422	$ 20,422
NPV of Project	-$600,135		NPV/TC	-75.02%							
Discount Rate	0.90%										

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